Lecture 13 – Global change

Global change

- What is Global Change?
- What drives Global Change?

Global change

- What is Global Change?
- What drives Global Change?
  - Solid earth
  - Atmosphere
  - Life
  - Continents
  - Sea level
  - Rocks
  - Biogeochemical
  - Hydrologic
  - Carbon

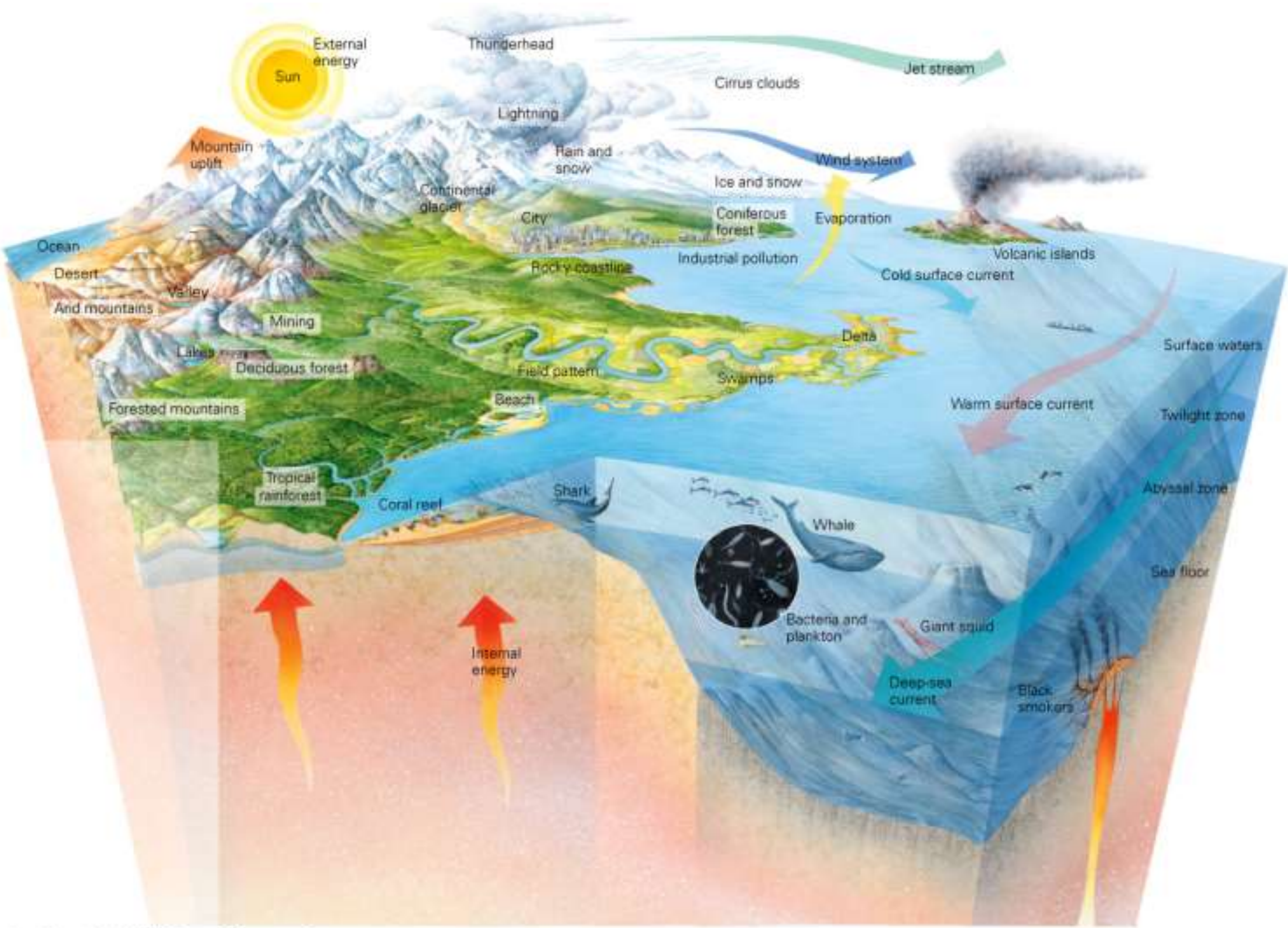
Global change

- What is weather?
- What is climate?

Global change

- Transformations or modifications of physical or biological components of Earth system
- Gradual vs catastrophic change
- Unidirectional vs cyclic changes

An entire system



Steady State

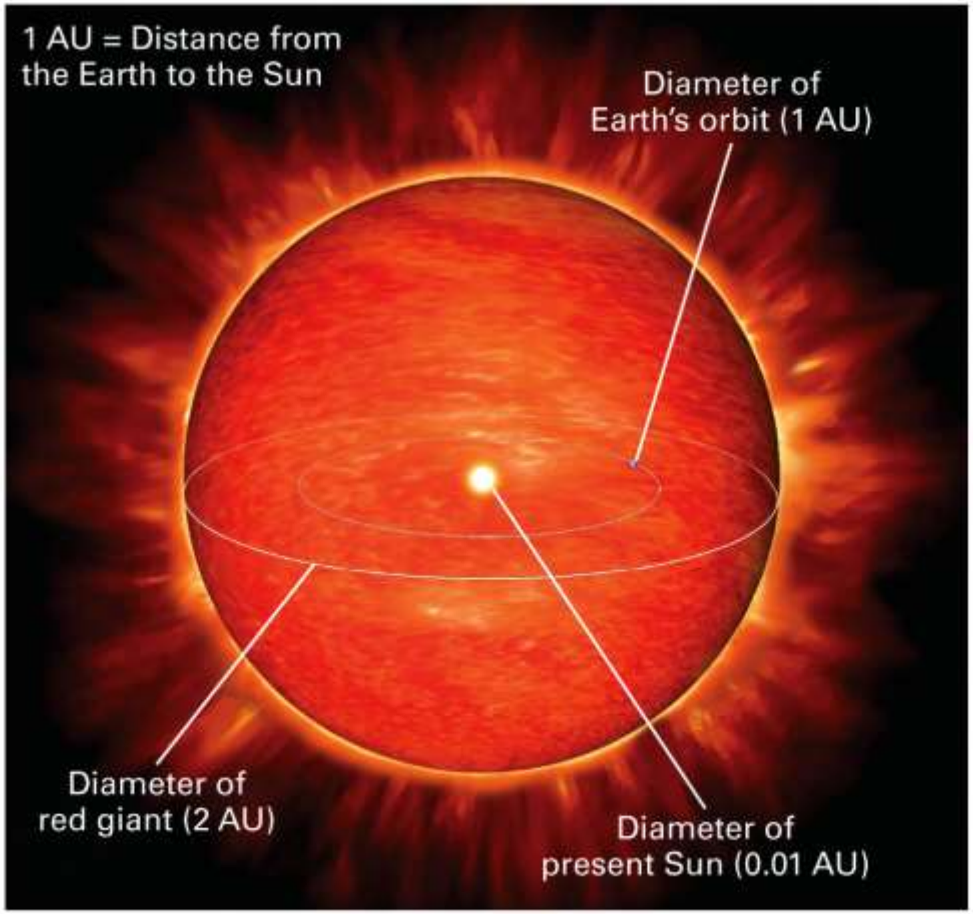
- What is steady state?
- What does thermodynamics say about Earth’s future?

Entropy

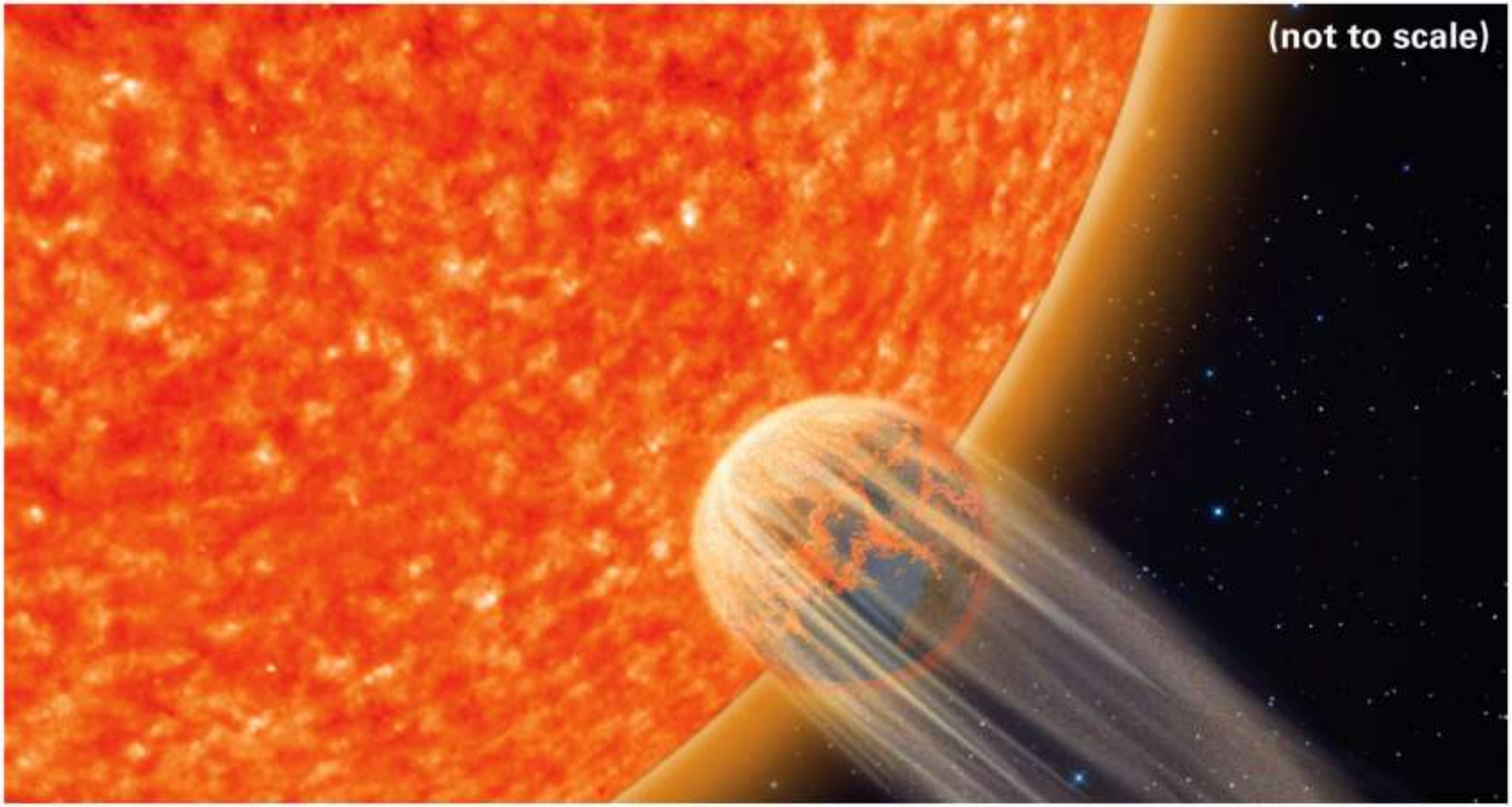
- Heat death of the universe!
- Each time a reaction happens, some of its energy is lost to entropy.
- Eventually all energy which could be used for work will be lost.

Geologic/Universe time is not human time

Geologic/Universe time is not human time



Geologic/Universe time is not human time



Measuring sea level

- What is ‘sea level’?

- How do we measure it?

Examples of tide gauge records

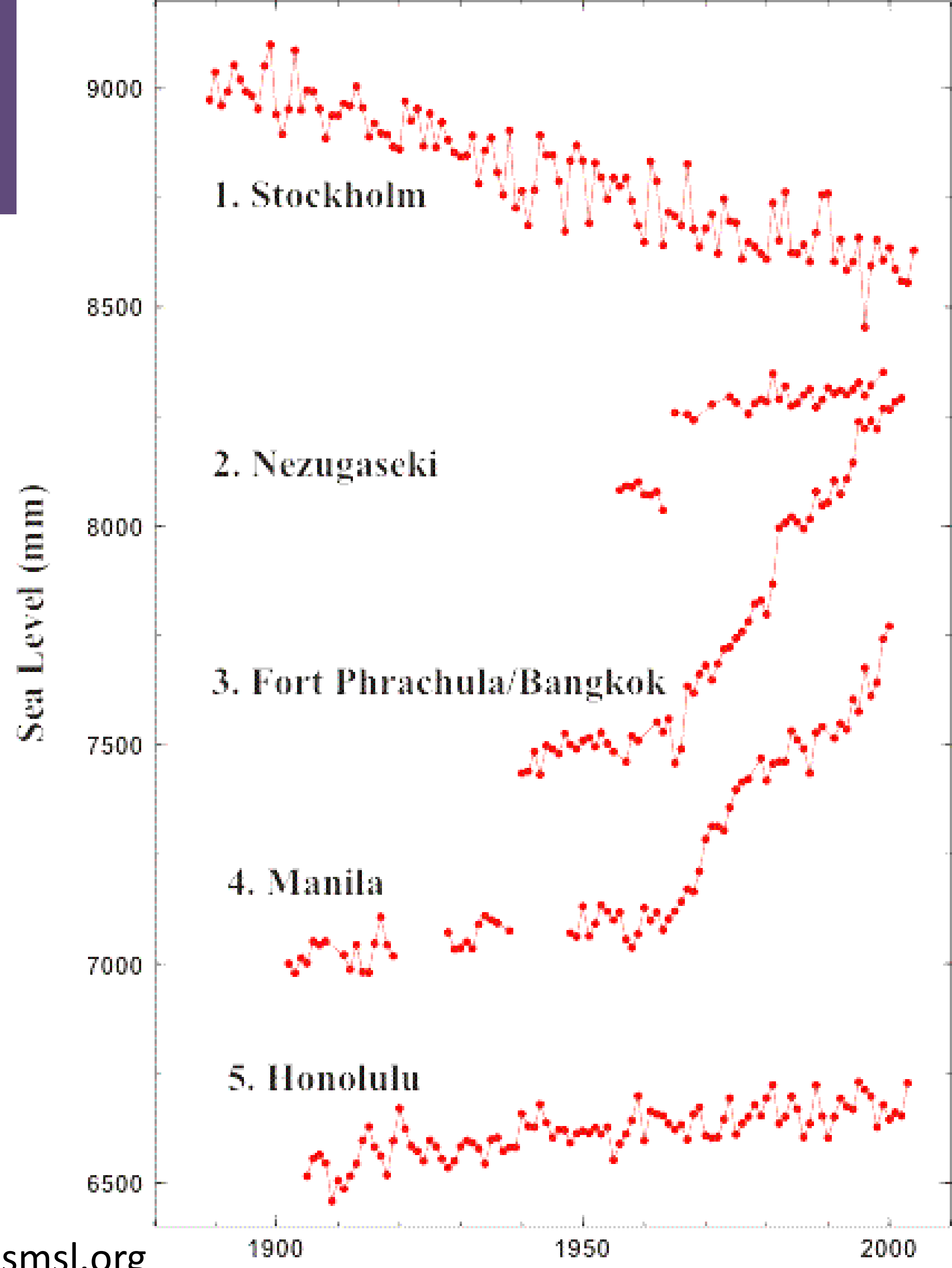


Image from www.psmsl.org

Isostatic vs eustatic sea level change

- Isostatic (local) sea level varies due to:

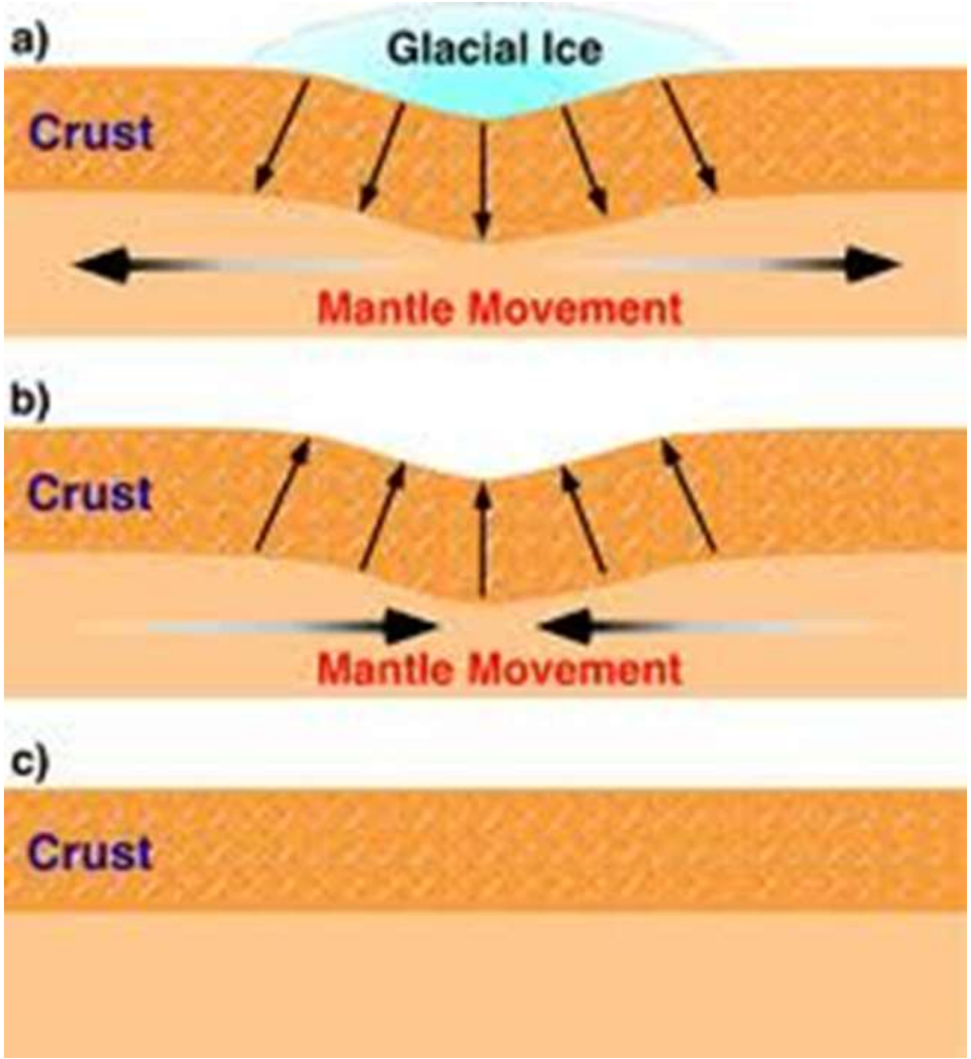
- Eustatic (global) sea level varies due to:

Isostatic vs eustatic sea level change

- Isostatic (local) sea level varies due to:
  - Movement of land surface e.g. loading, plate tectonics
  - Atmospheric pressure
  - Ocean currents
  - Temperature of local water currents

- Eustatic (global) sea level varies due to:
  - Change in mass of ocean water e.g. ice sheet melting, or increased evaporation
  - Change in volume of ocean basins (over millions of years)
  - Density changes of water (thermal expansion or contraction)

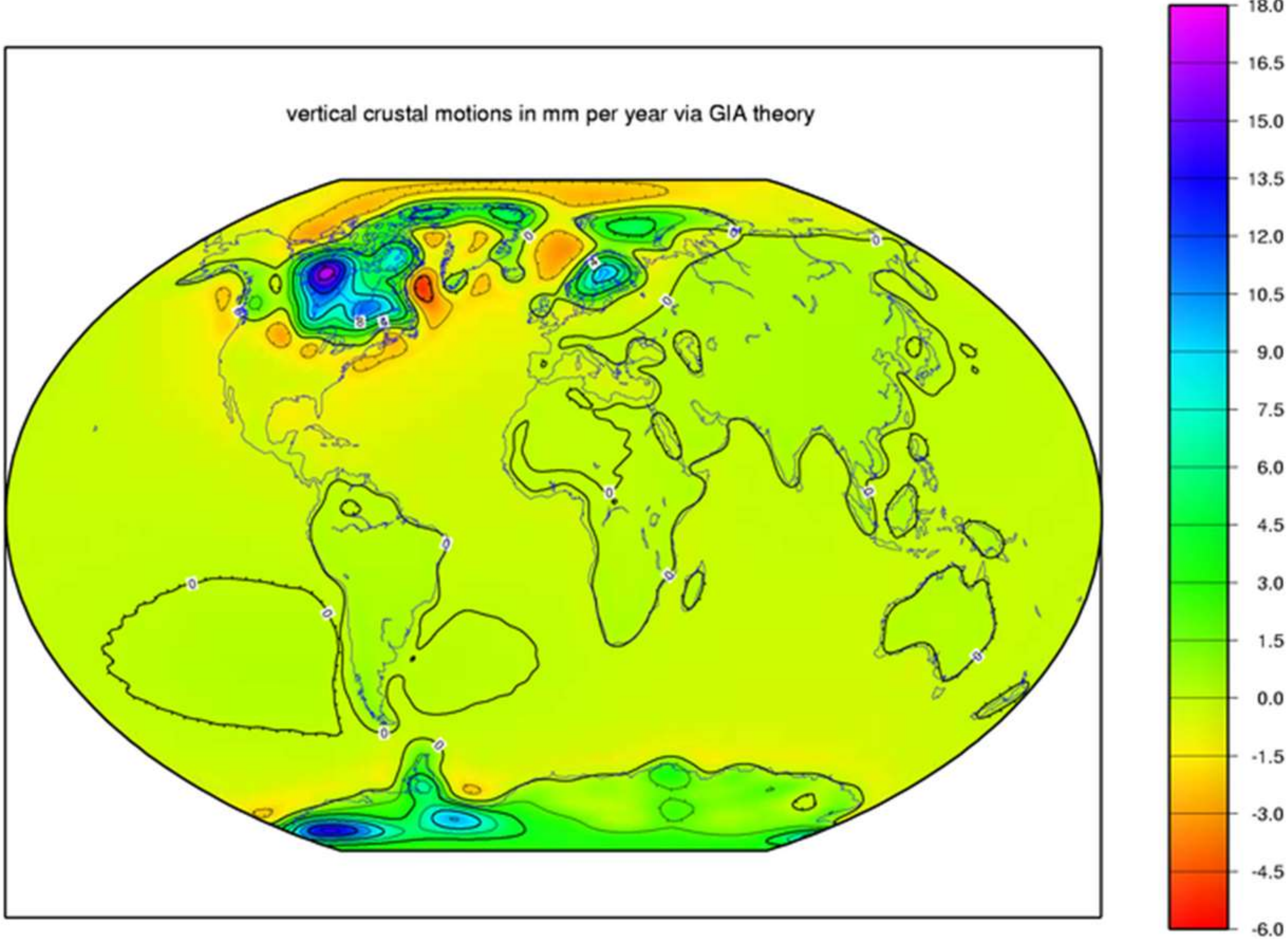
Isostatic sea level change: Glacial loading and rebound



Isostatic sea level change: Glacial loading and rebound

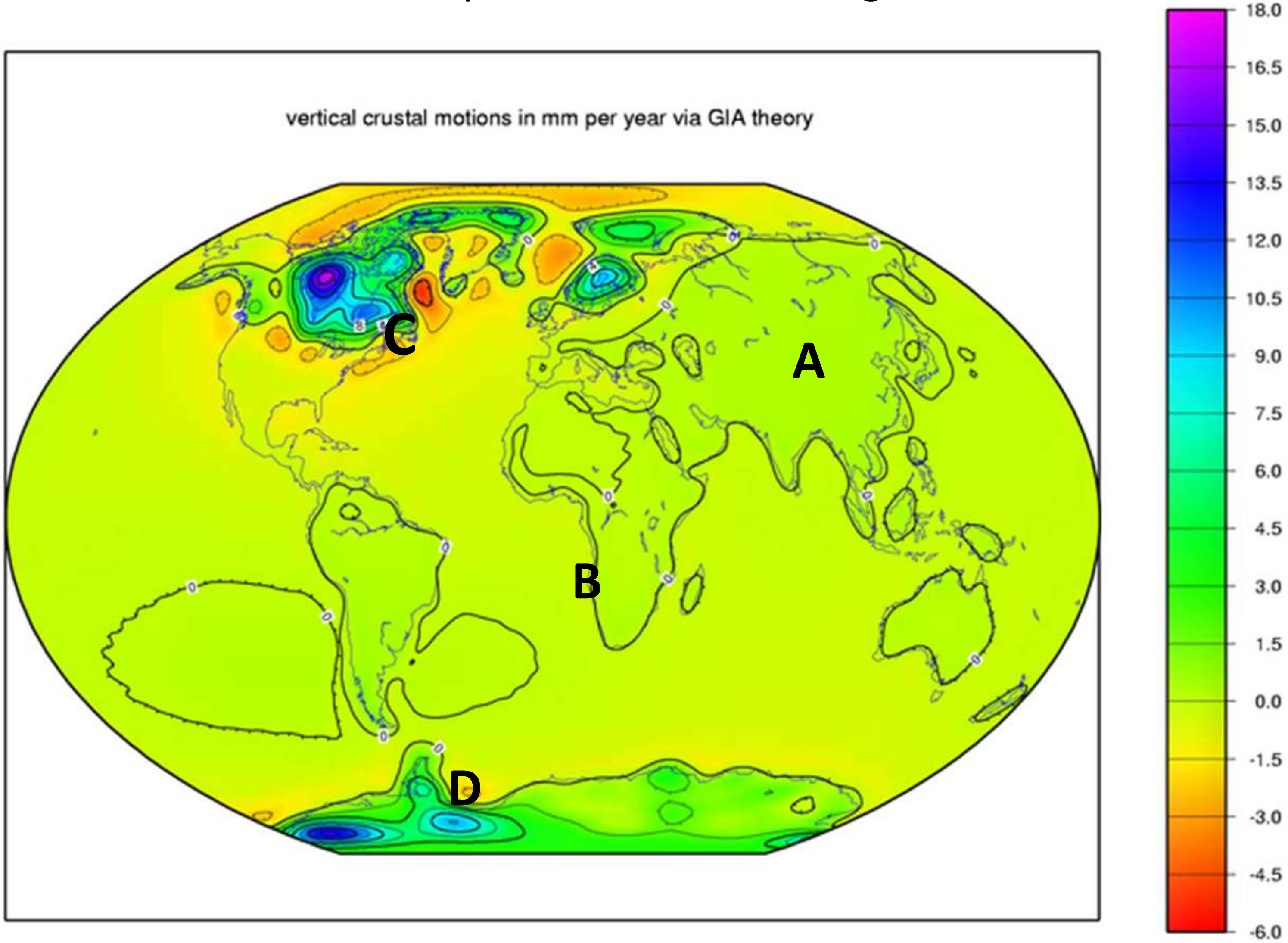
Mike Beauregard from Nunavut, Canada

Isostatic sea level change: Glacial loading and rebound



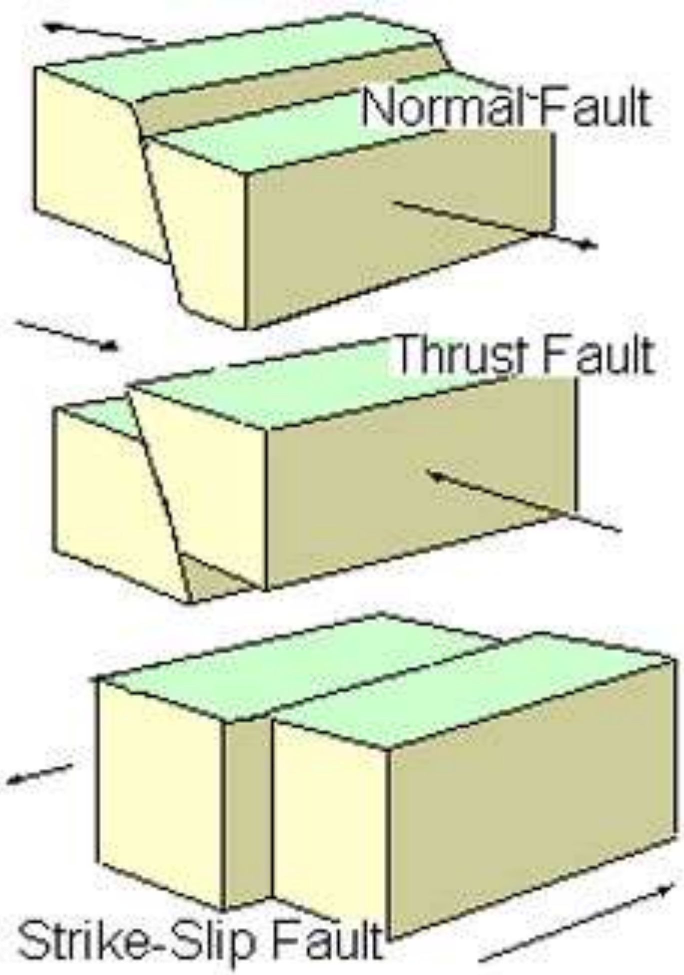
Isostatic sea level change: Glacial loading and rebound

Where would be the best place to measure global sea level changes?



Isostatic sea level change: Plate tectonics

- Plate boundaries sometimes occur close to the edges of continents
- Some areas uplifting = local sea level fall
- Some areas subsiding = local sea level rise
- Earthquakes result in sudden changes in sea level



Isostatic sea level change: Plate tectonics

e.g. 3m rise in the land level after 8.0 magnitude earthquake in Solomon islands in 2007 left huge areas of coral reef exposed

Photo credit: Herald Sun

Examples of tide gauge records

Which of these locations might have experienced an earthquake?

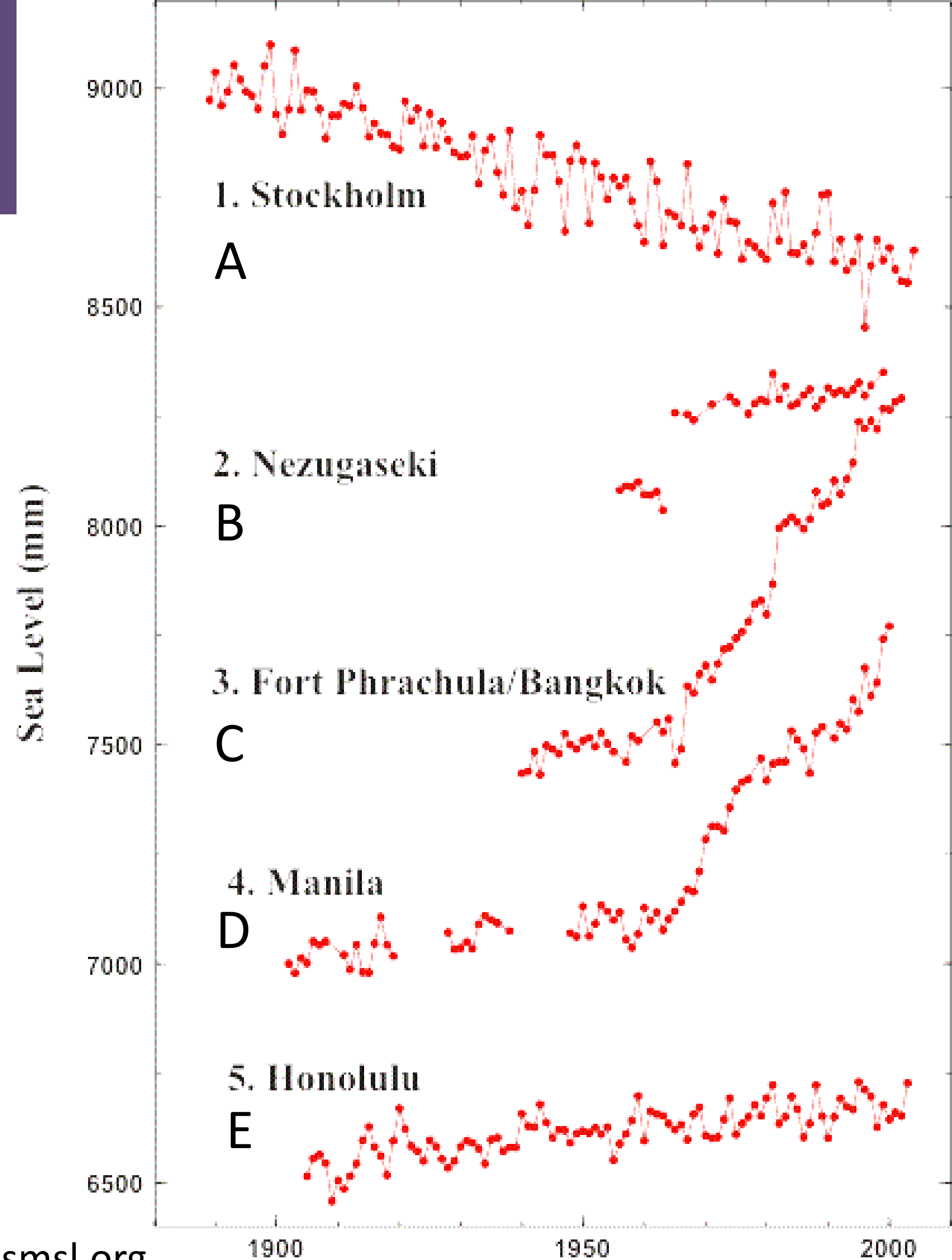
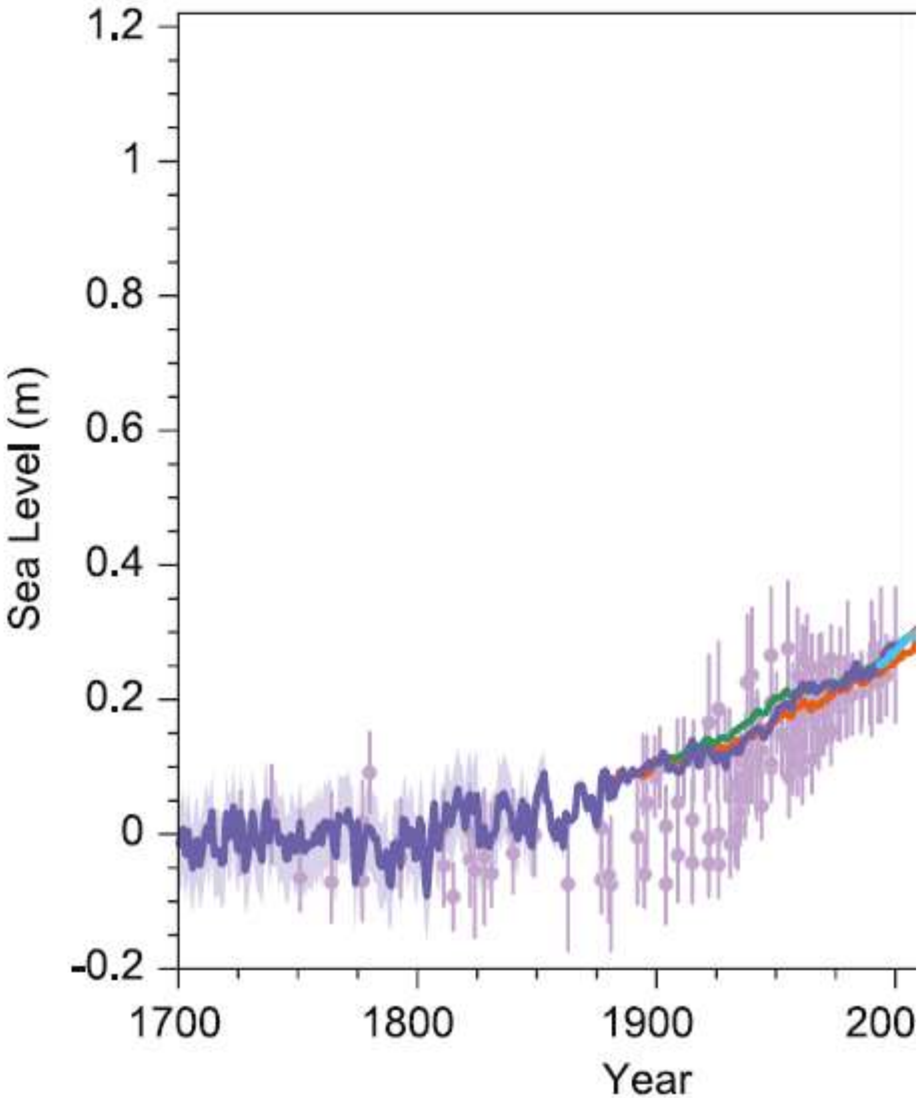


Image from www.psmsl.org

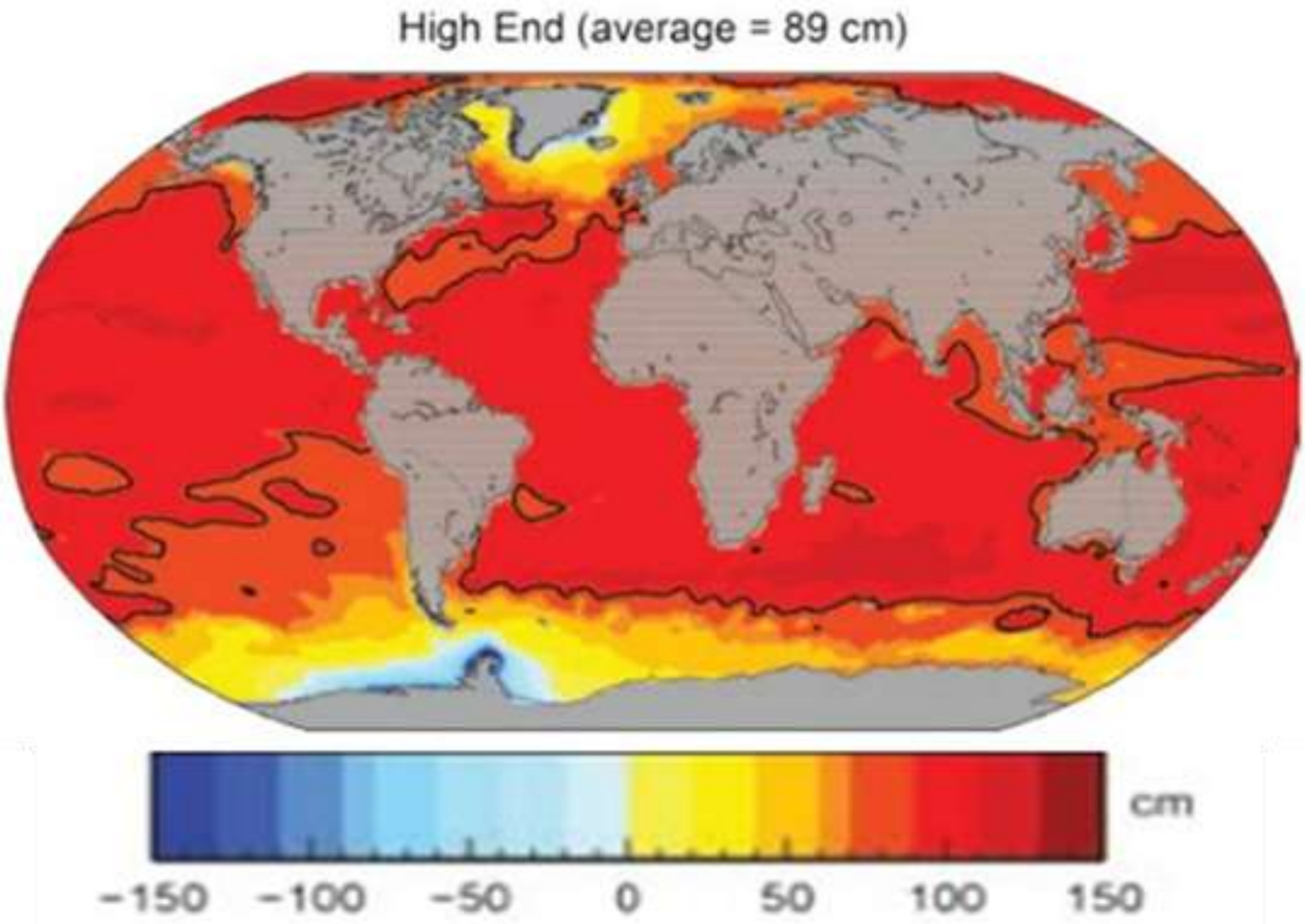
Observed eustatic (global) sea level rise

Reconstructed sea level for past 300 years accounting for isostatic factors



IPCC AR5 Fig 13.27

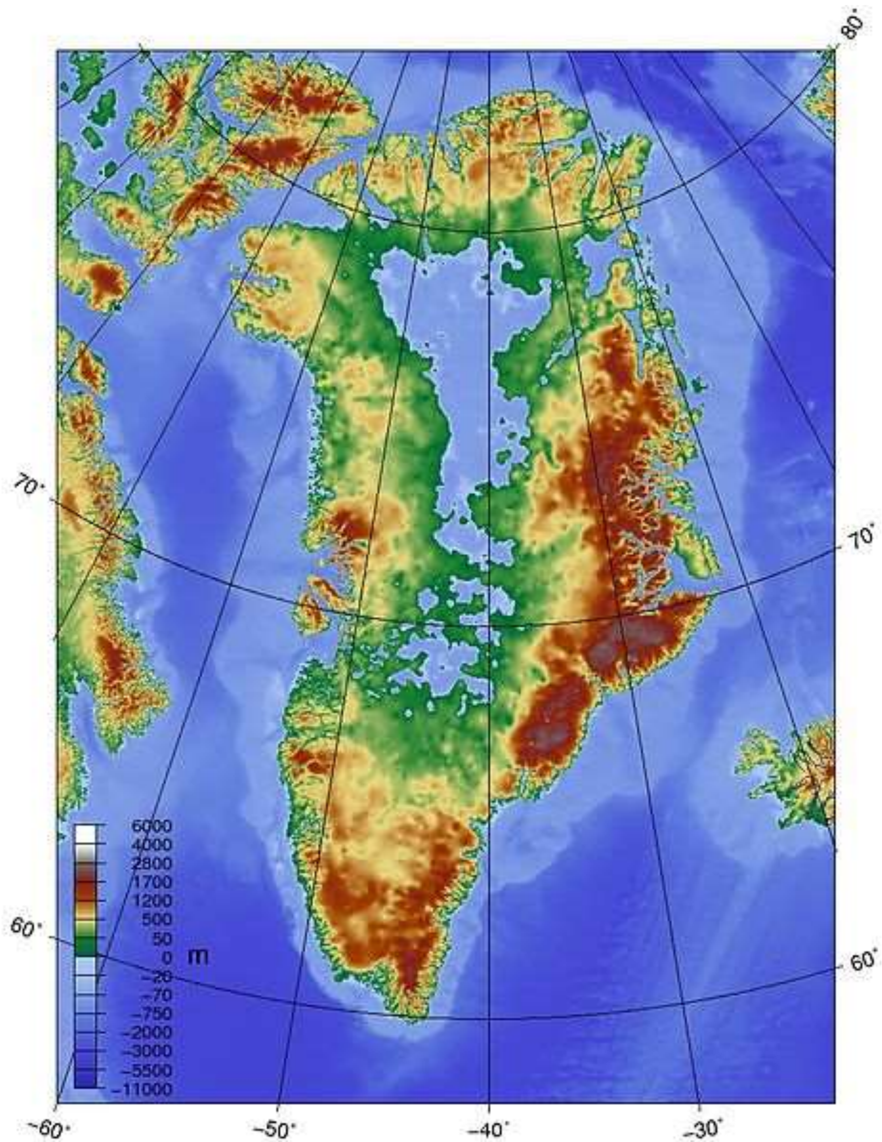
Future sea level rise



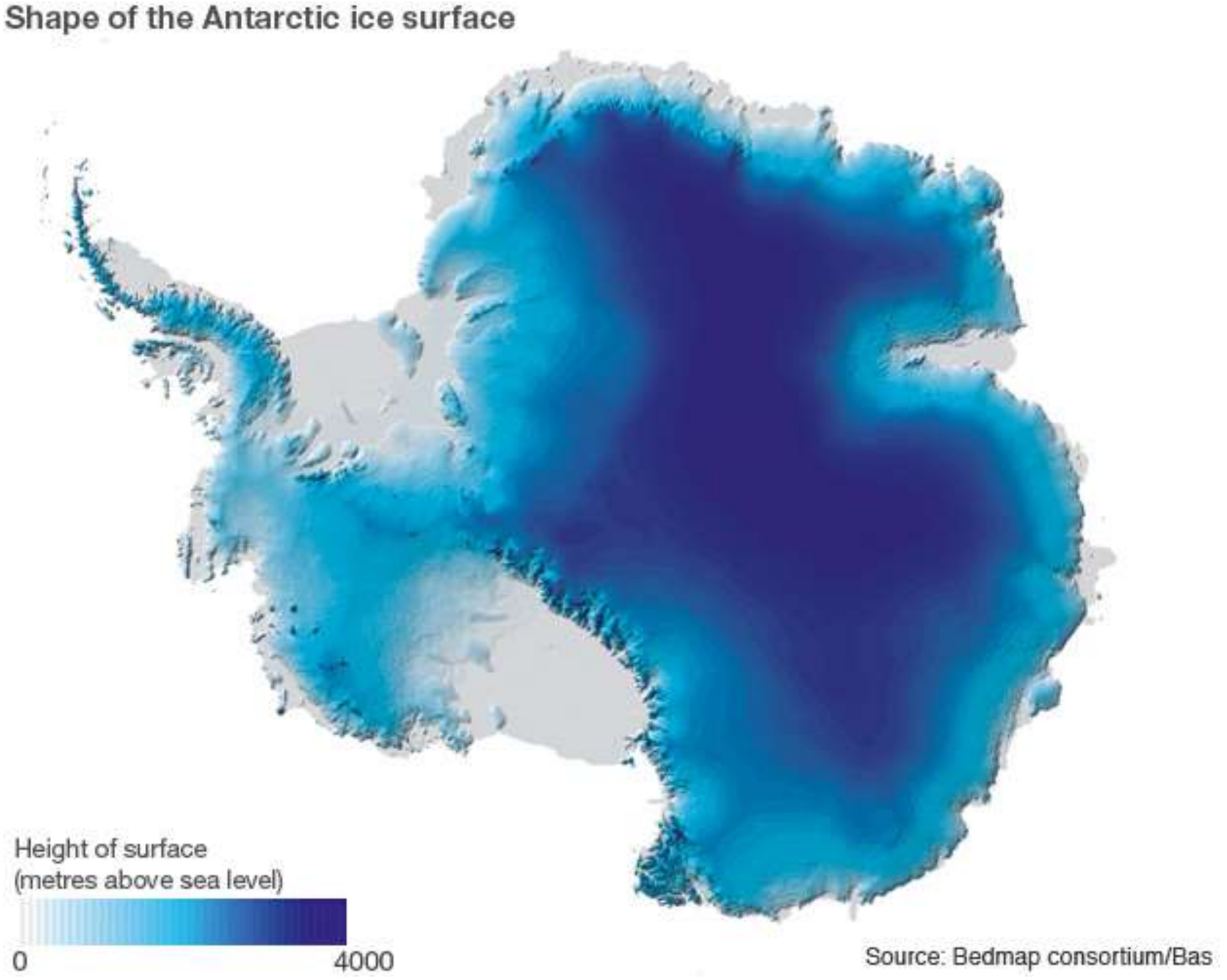
Greenland Ice Sheet

- 1.7 million km^2
- Thickness ~ 2km
- Volume ~ 2.27 million km^3
- Sea level rise equivalent of 6.5 m
- Ice up to 110,000 years old (maybe a bit older)

Greenland Ice Sheet



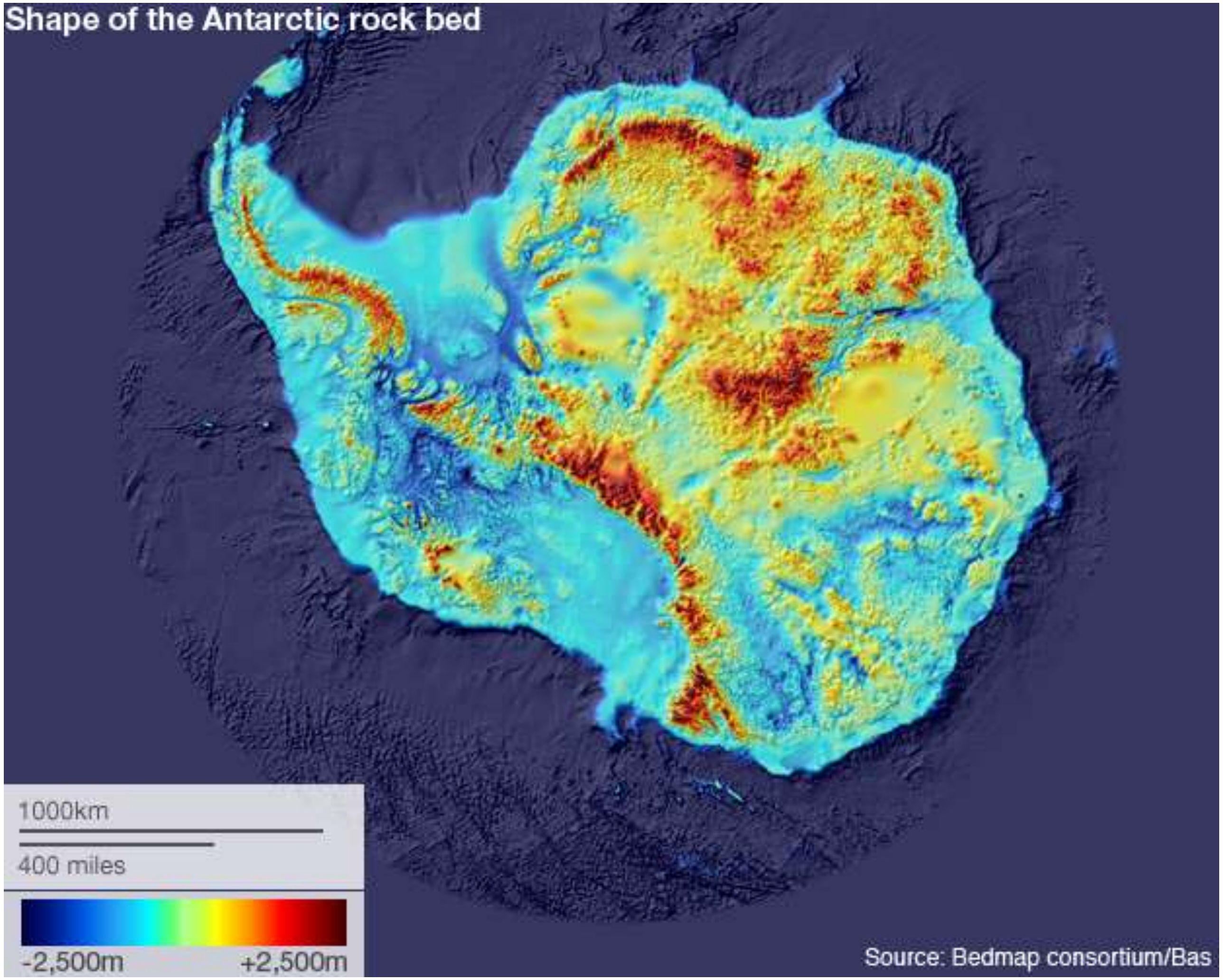
Antarctic Ice Sheet



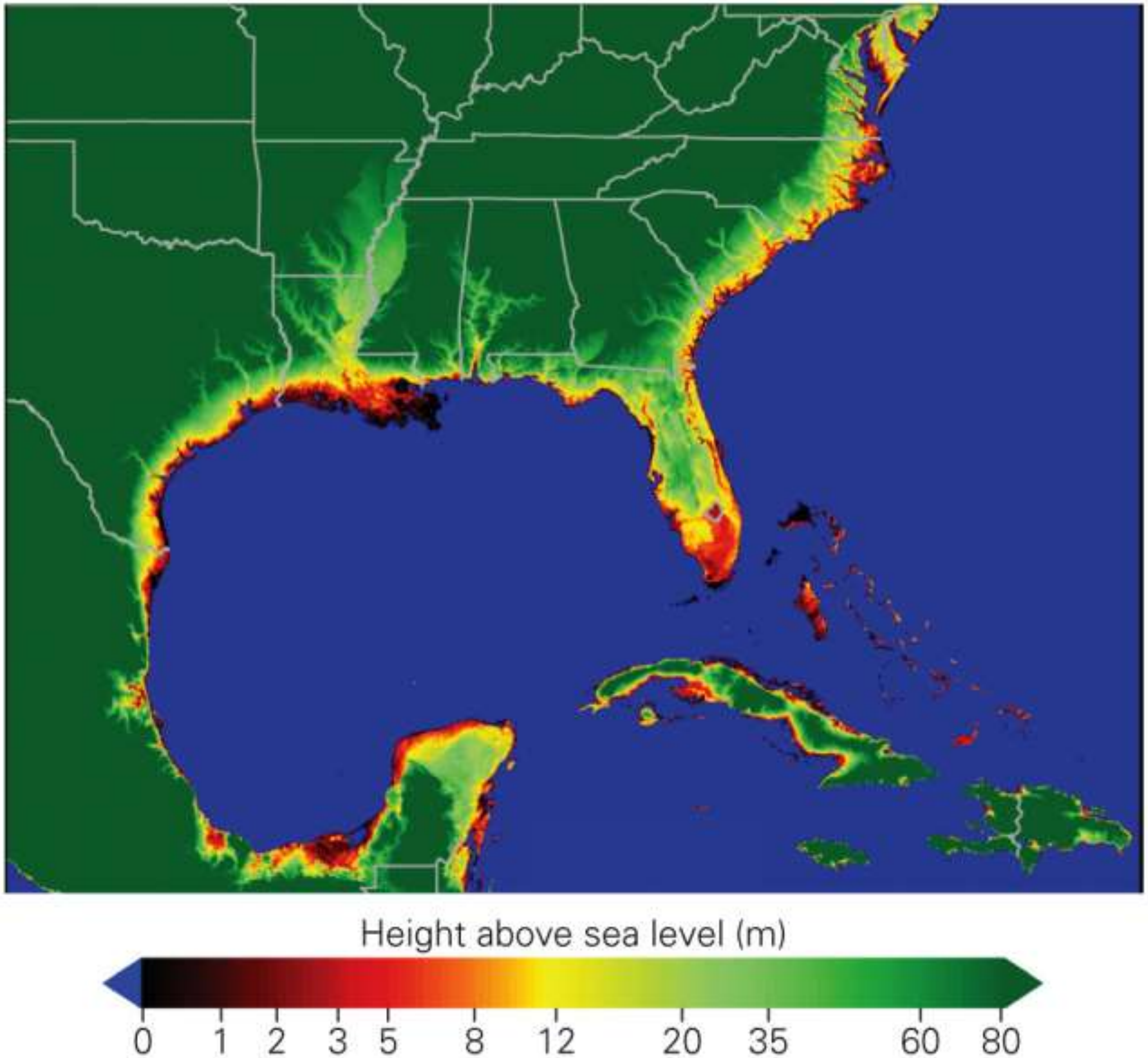
- 12.3 million km^2
- Thickness = 2 km
- Volume ~ 26.5 million km^3
- Sea level rise equivalent of up to 73m
- Ice up to 1 million years old

Antarctic Ice Sheet

How do we work out how stable the Antarctic ice sheet is?

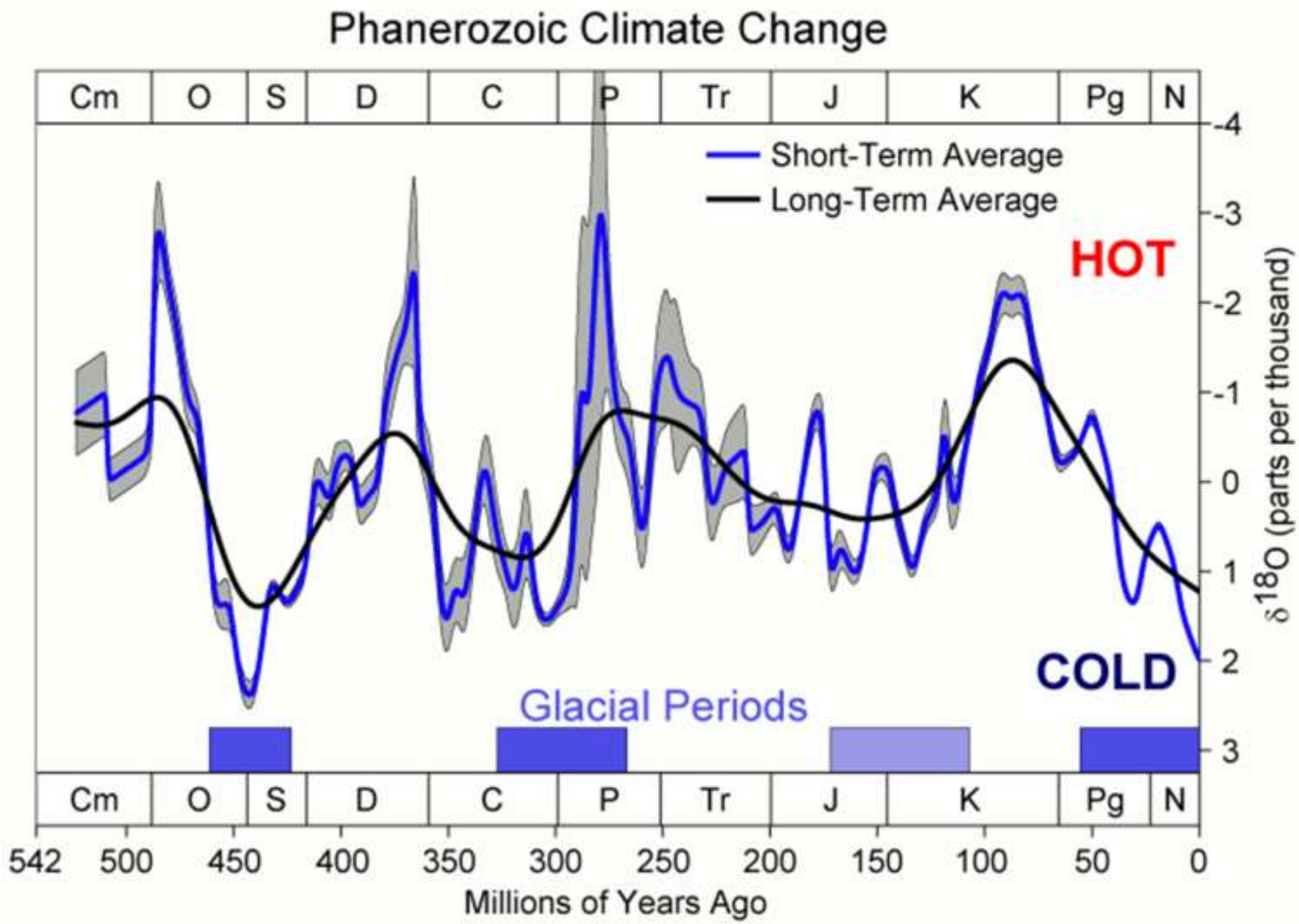


http://www.andrill.org/st


Height above sea level (m)
0 1 2 3 5 8 12 20 35 60 80

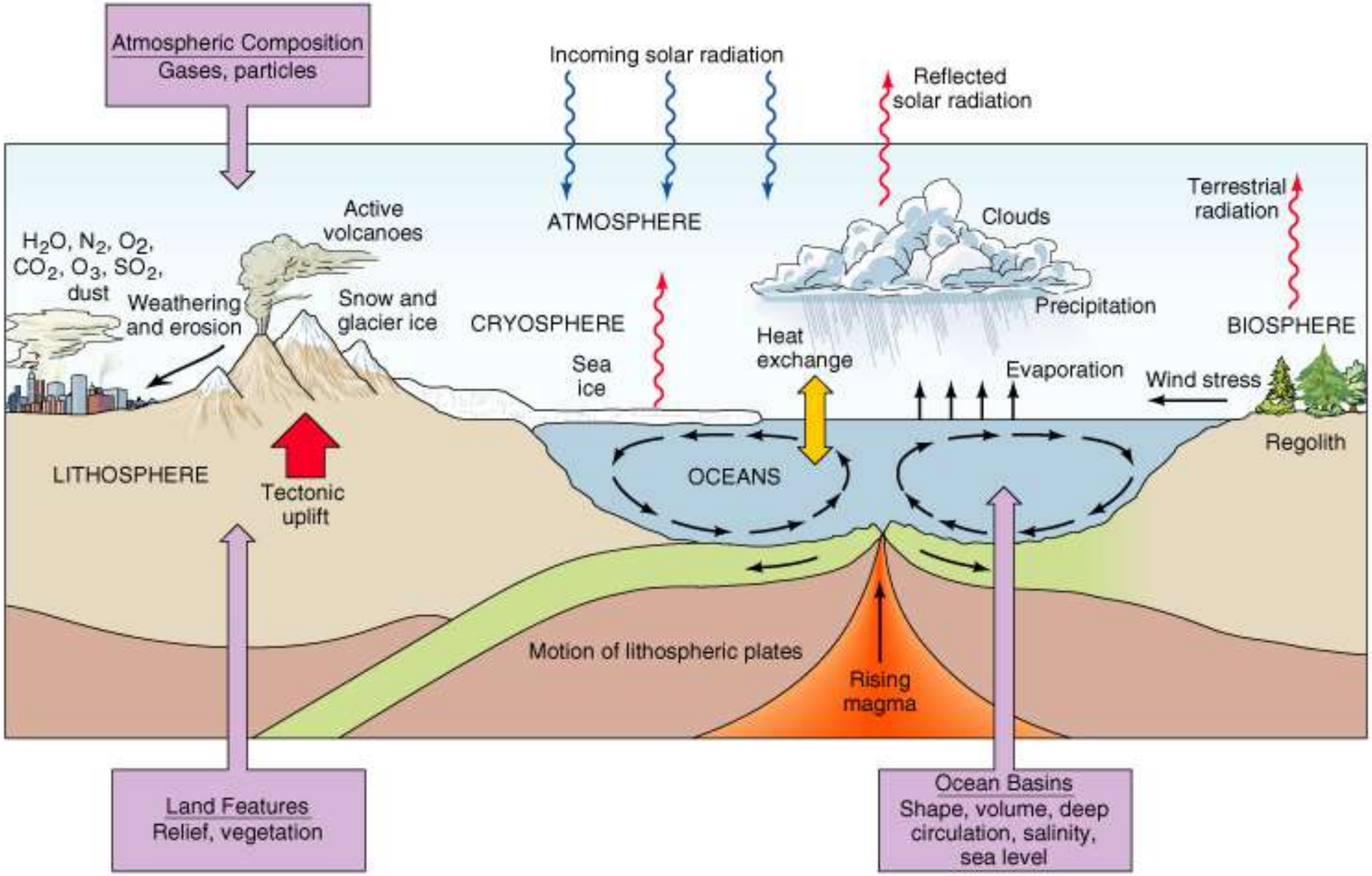
Global climate change

- Has happened repeatedly over Earth's history



"The Climate System"

Characterized by CHANGE



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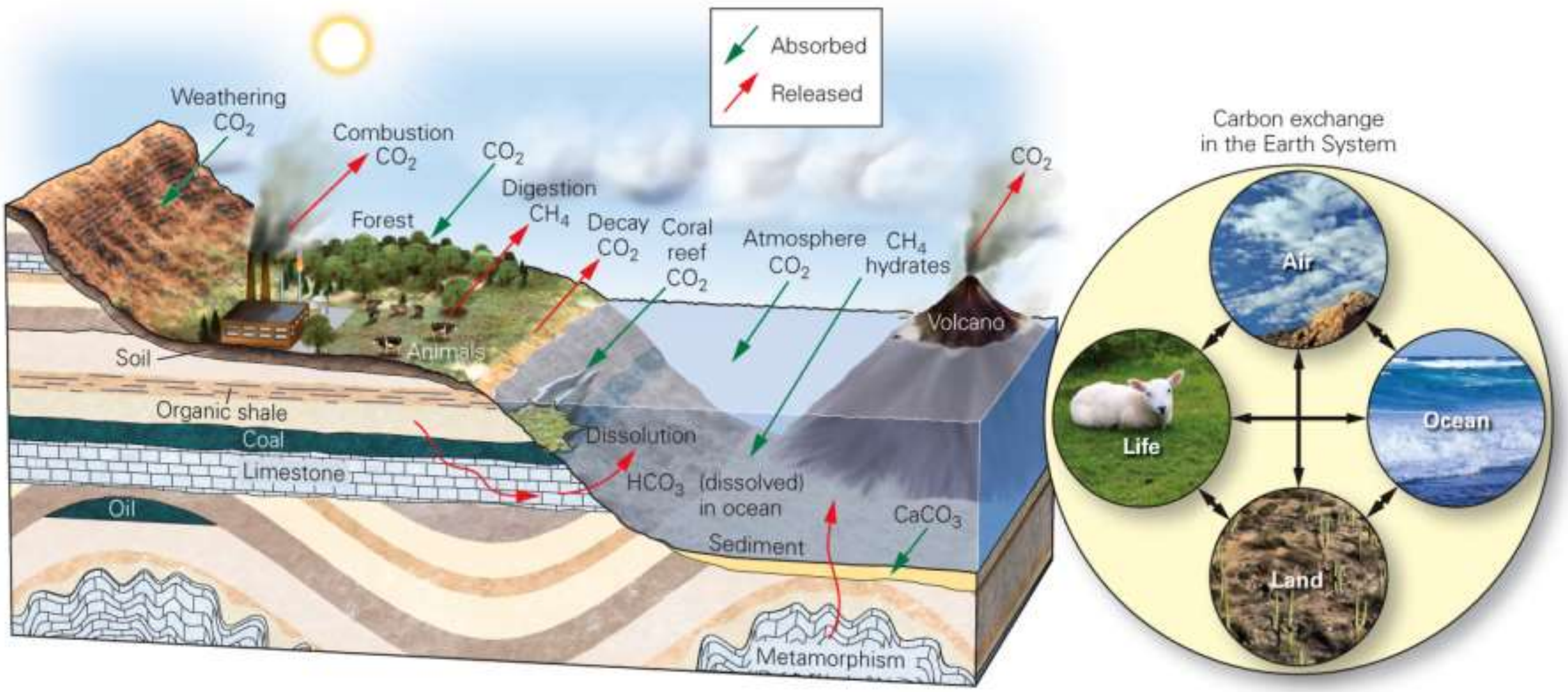

Past Climate: how do we know?

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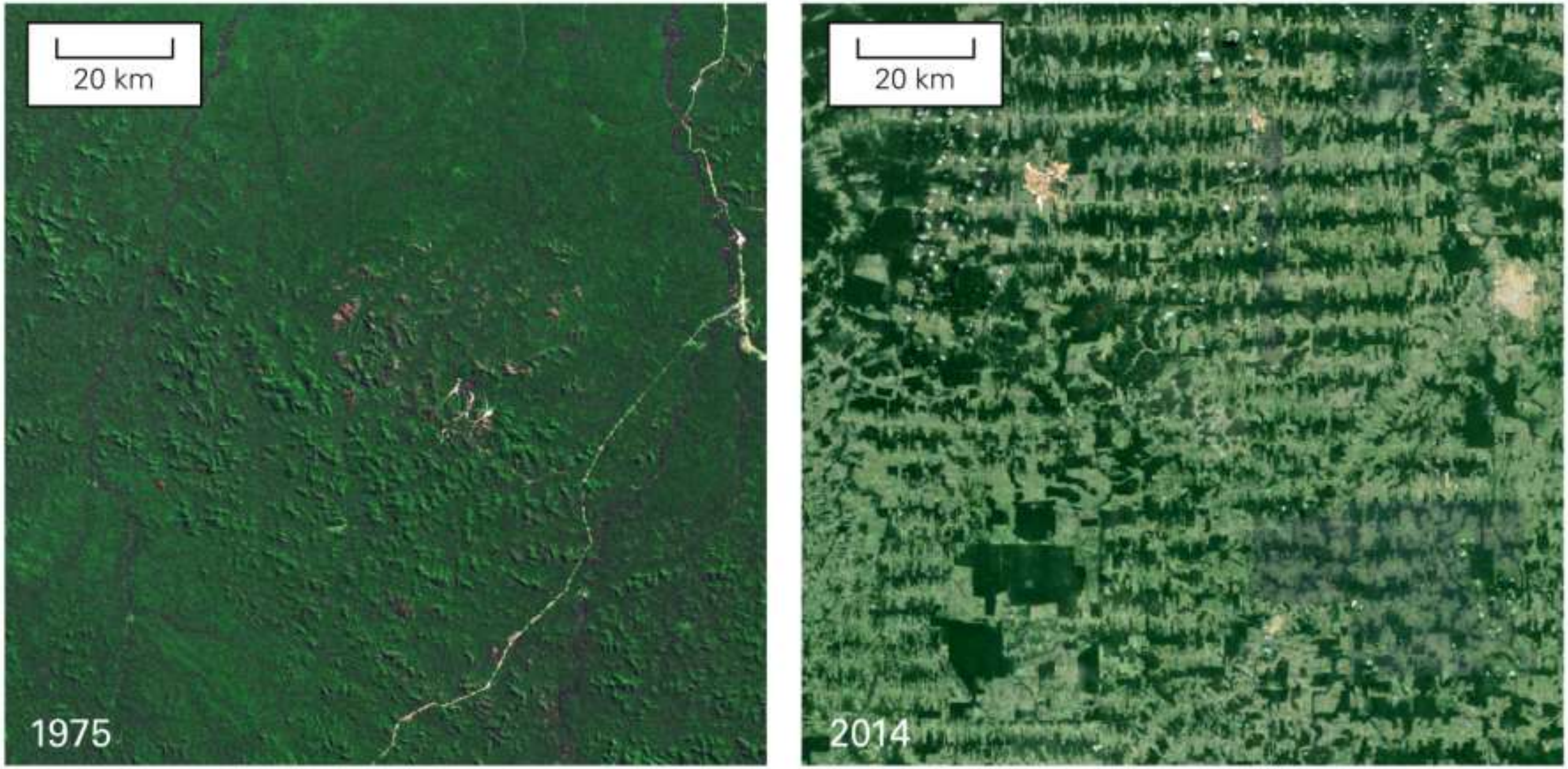

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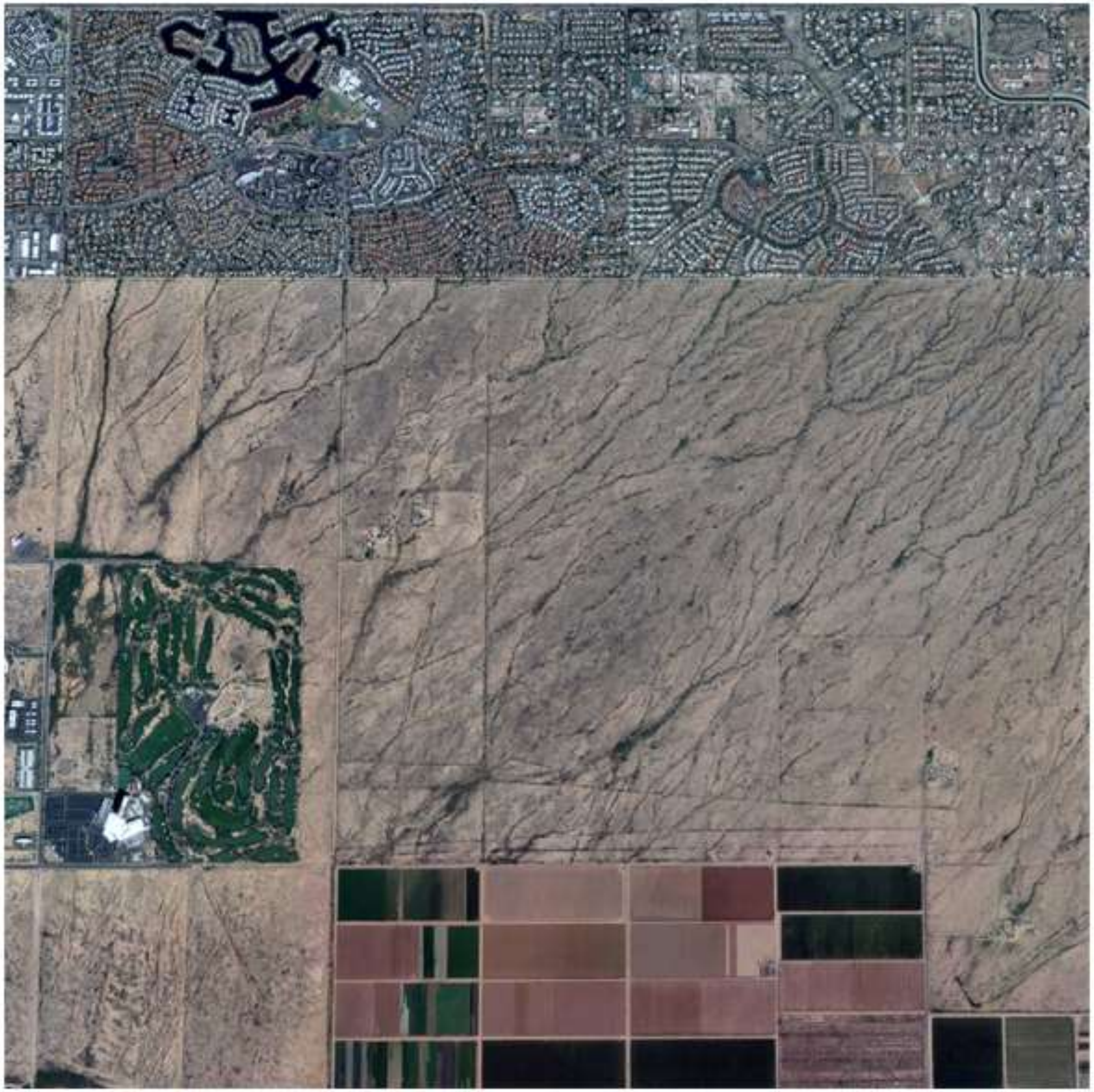
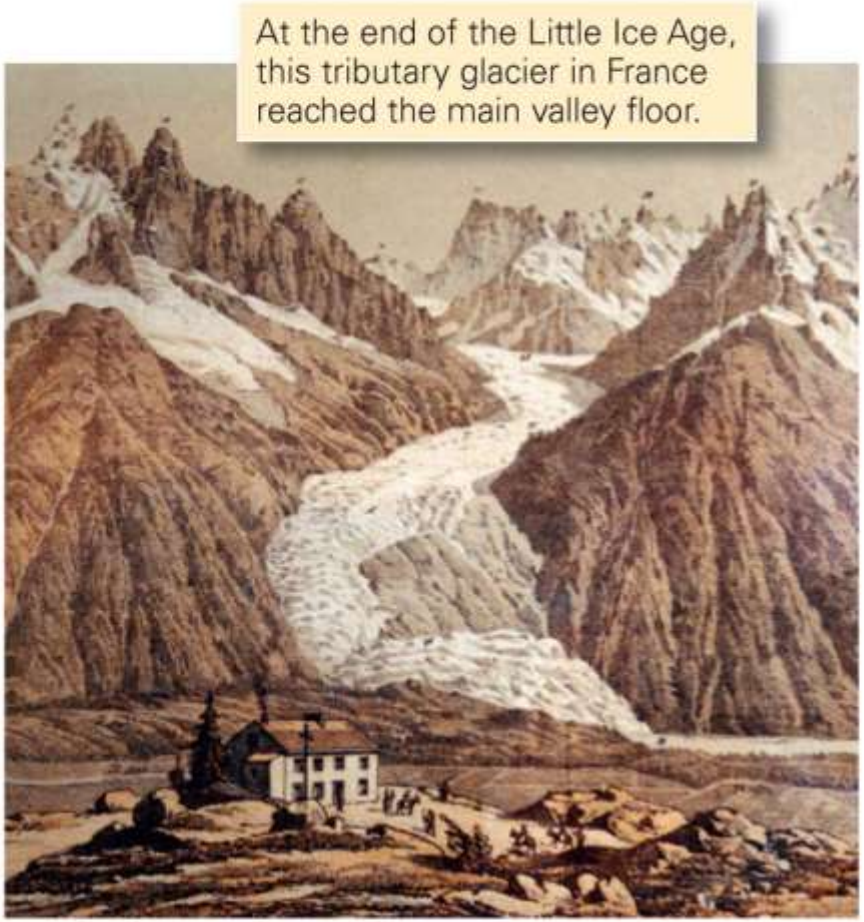


Past Climate: how do we know?



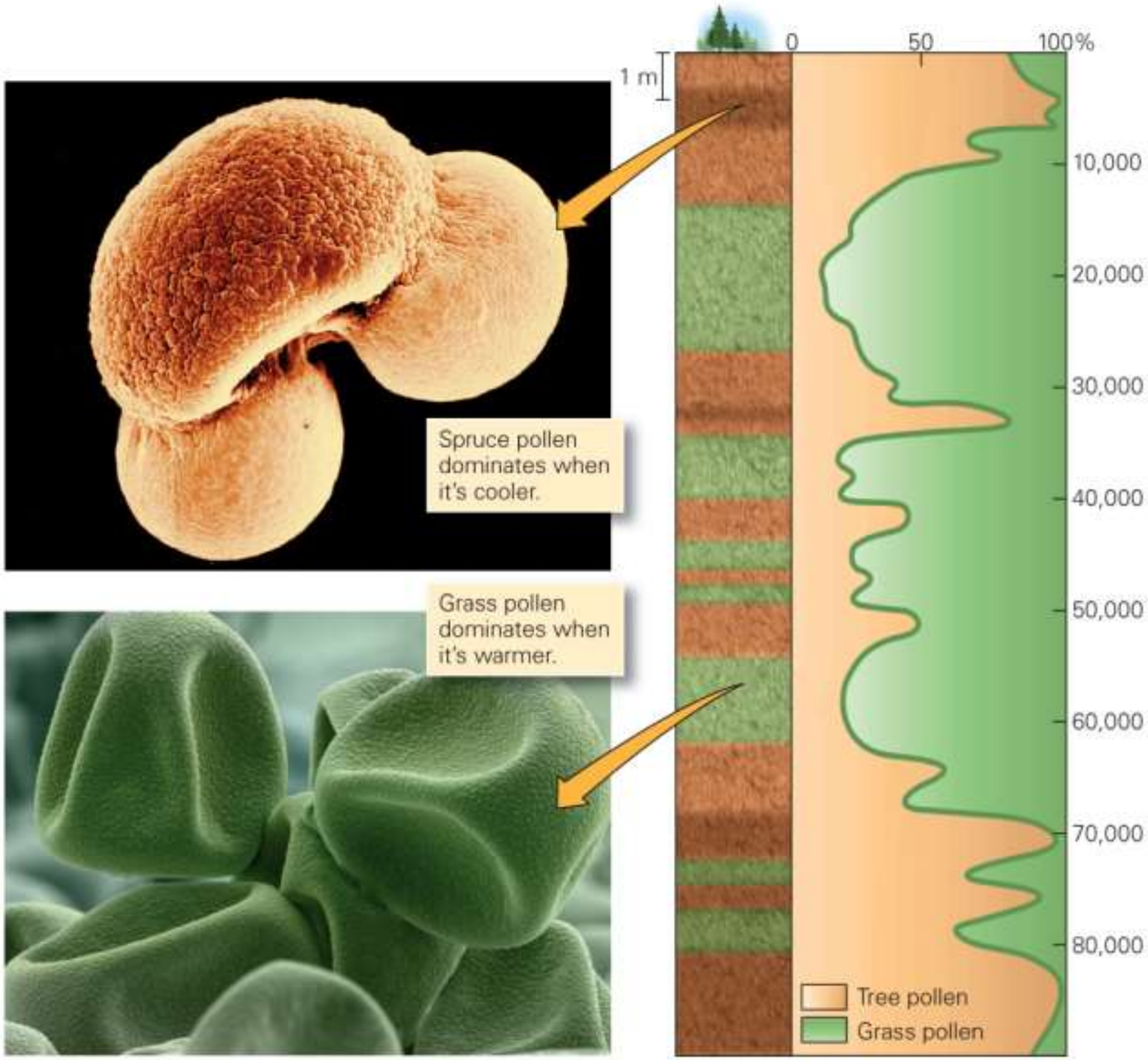
Past Climate: how do we know?

Past Climate: how do we know?

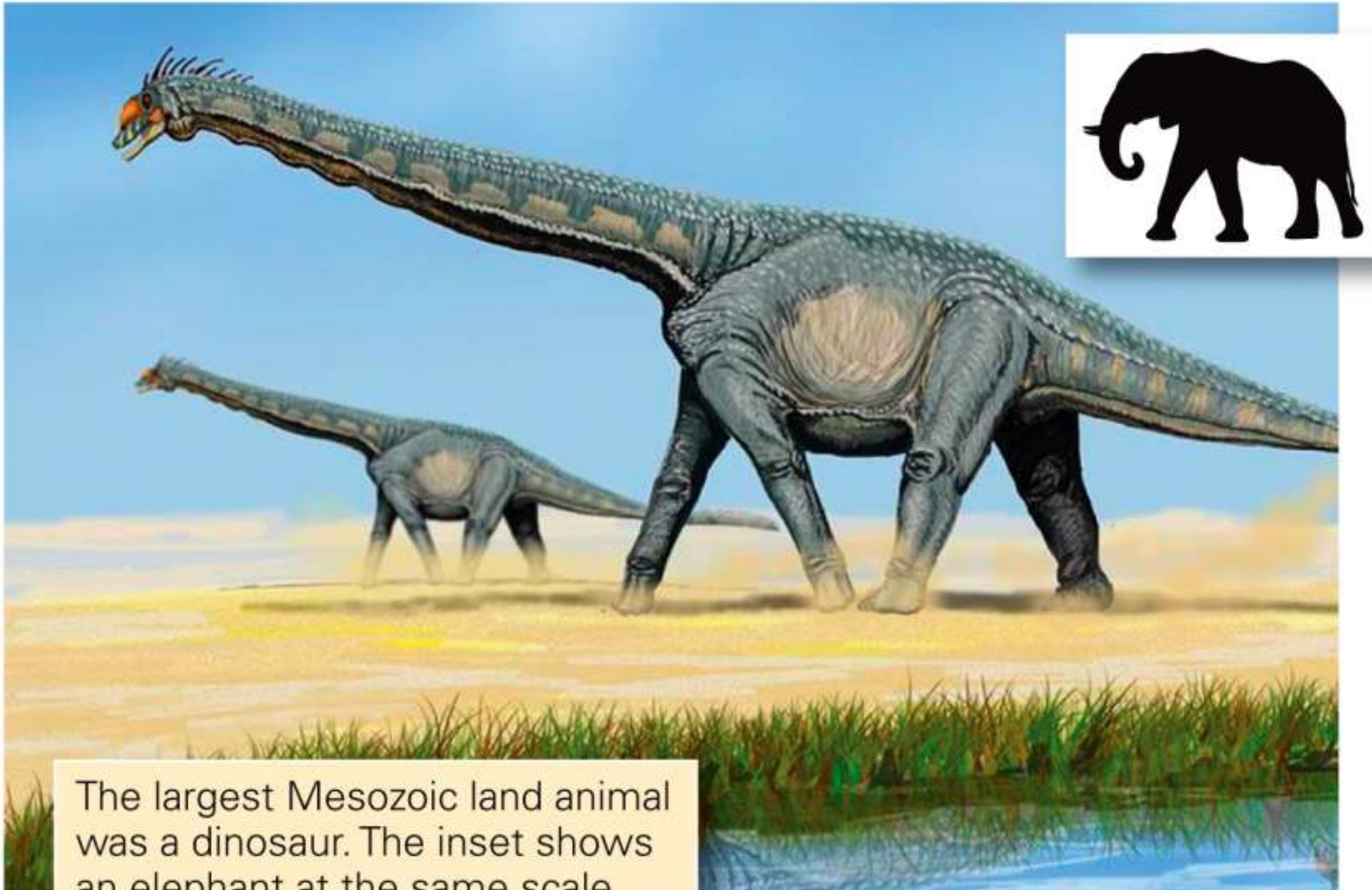
1. Instrumental Record
   (recent, ~1800s to present)
2. Geologic Record
   - fossils
   - landscape features (sand dunes, dry lakes/rivers, moraines etc)
3. Proxy Records
   "records of natural events that are controlled by, and closely mimic, climate"



Geologic Record



Geologic Record



The largest Mesozoic land animal was a dinosaur. The inset shows an elephant at the same scale.

Past Climate: Proxy Records

Natural "layered" records e.g.

a) Tree rings

b) Lake/ocean sediment

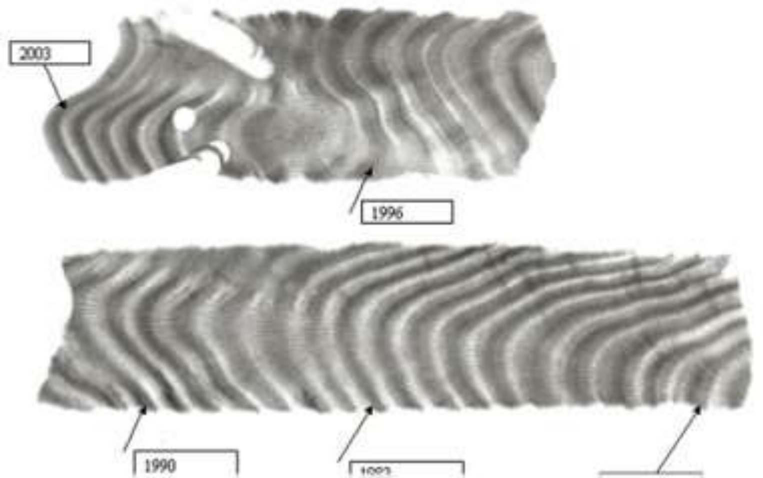
c) Ice cores

d) Others include cave deposits, corals etc

http://www.theage.com.au/news/national/great-barrier-reef-hurt-by-farming/2007/05/31/1180205427882.html

www.cr.nps.gov/worldheritage/caca.htm

http://www.ncdc.noaa.gov/paleo/pubs/partin2007/stalagmite.jpg



http://www3.aims.gov.au/pages/research/organic-geochemistry/cccgsag/images01/coral-density-bands-dated-480.jpg

Evaporating water

Three stable oxygen isotopes:

^{16}O ^{17}O ^{18}O

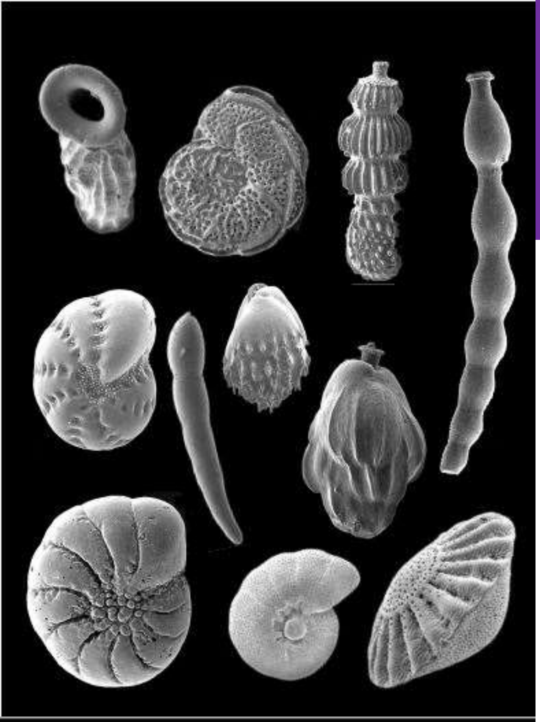
How does evaporation work?

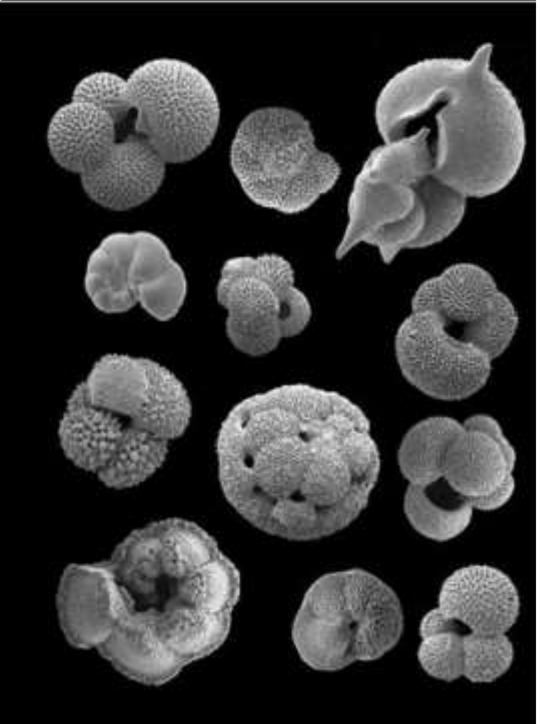
Evaporating water

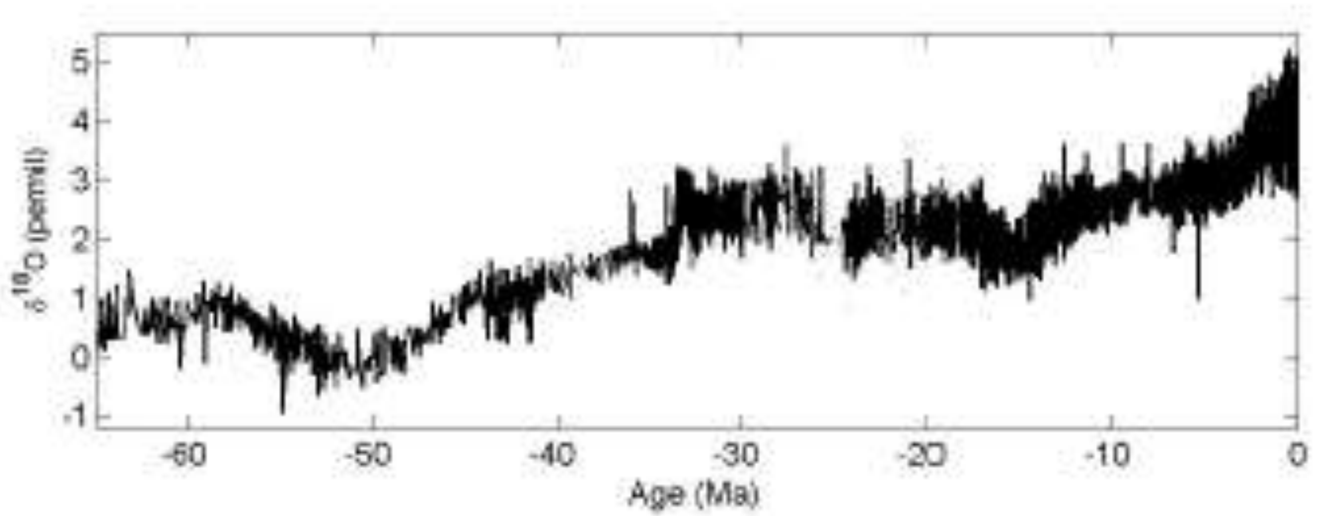
Which water will require more energy to evaporate?

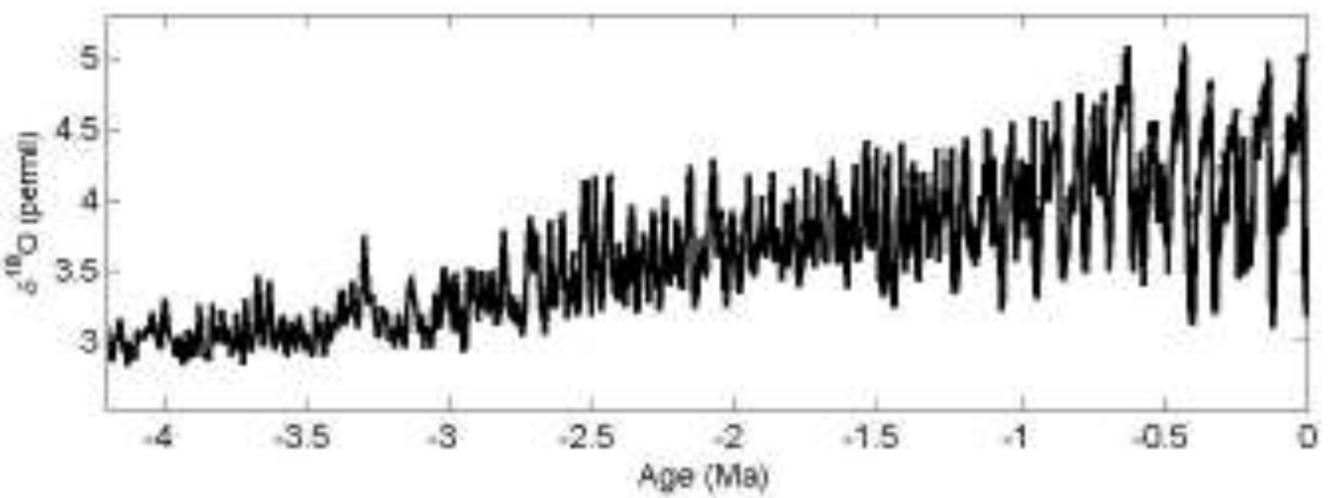
$H_2{}^{16}O$ $H_2{}^{17}O$ $H_2{}^{18}O$

Ocean $\delta^{18}O$ record

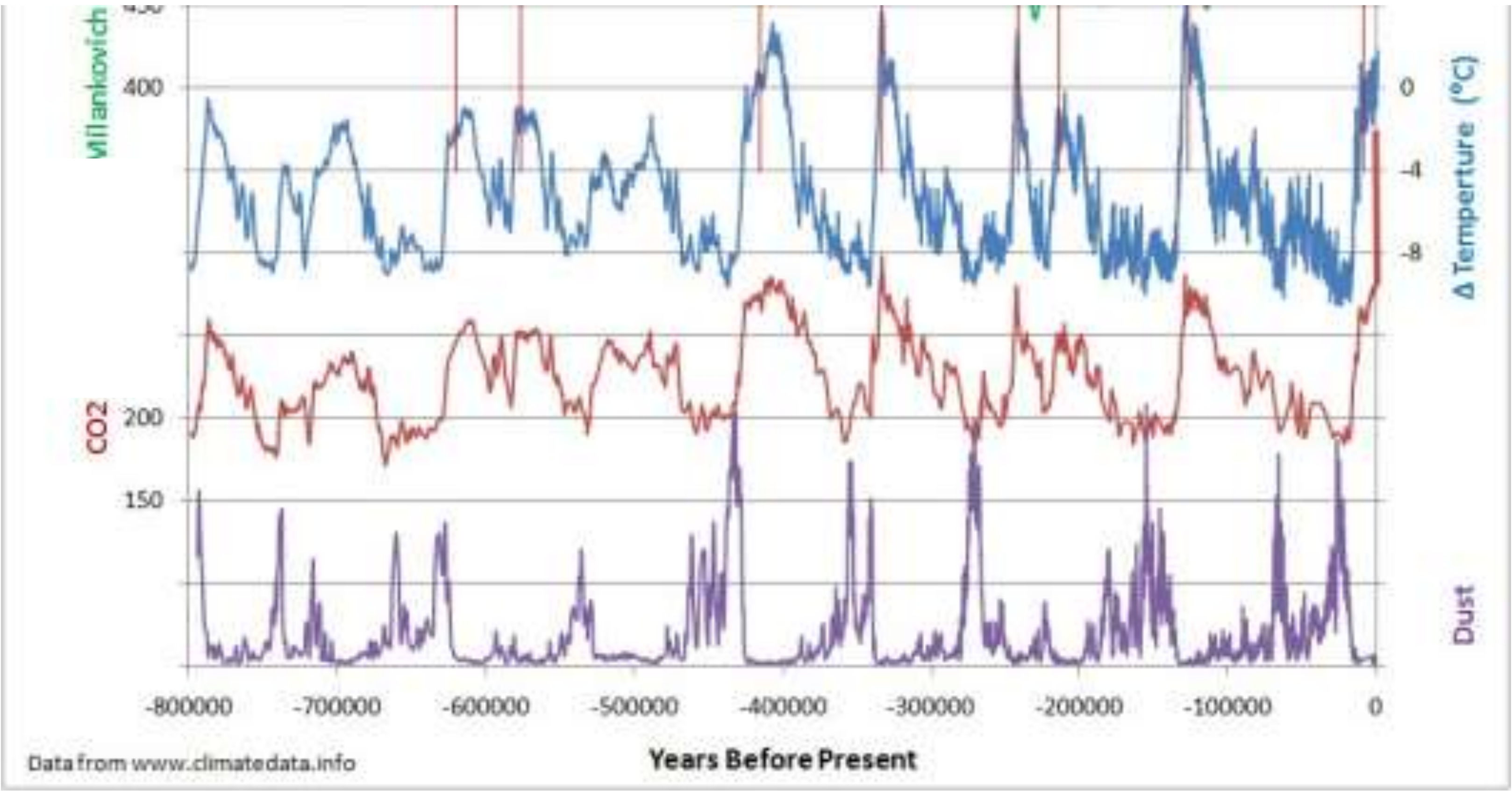




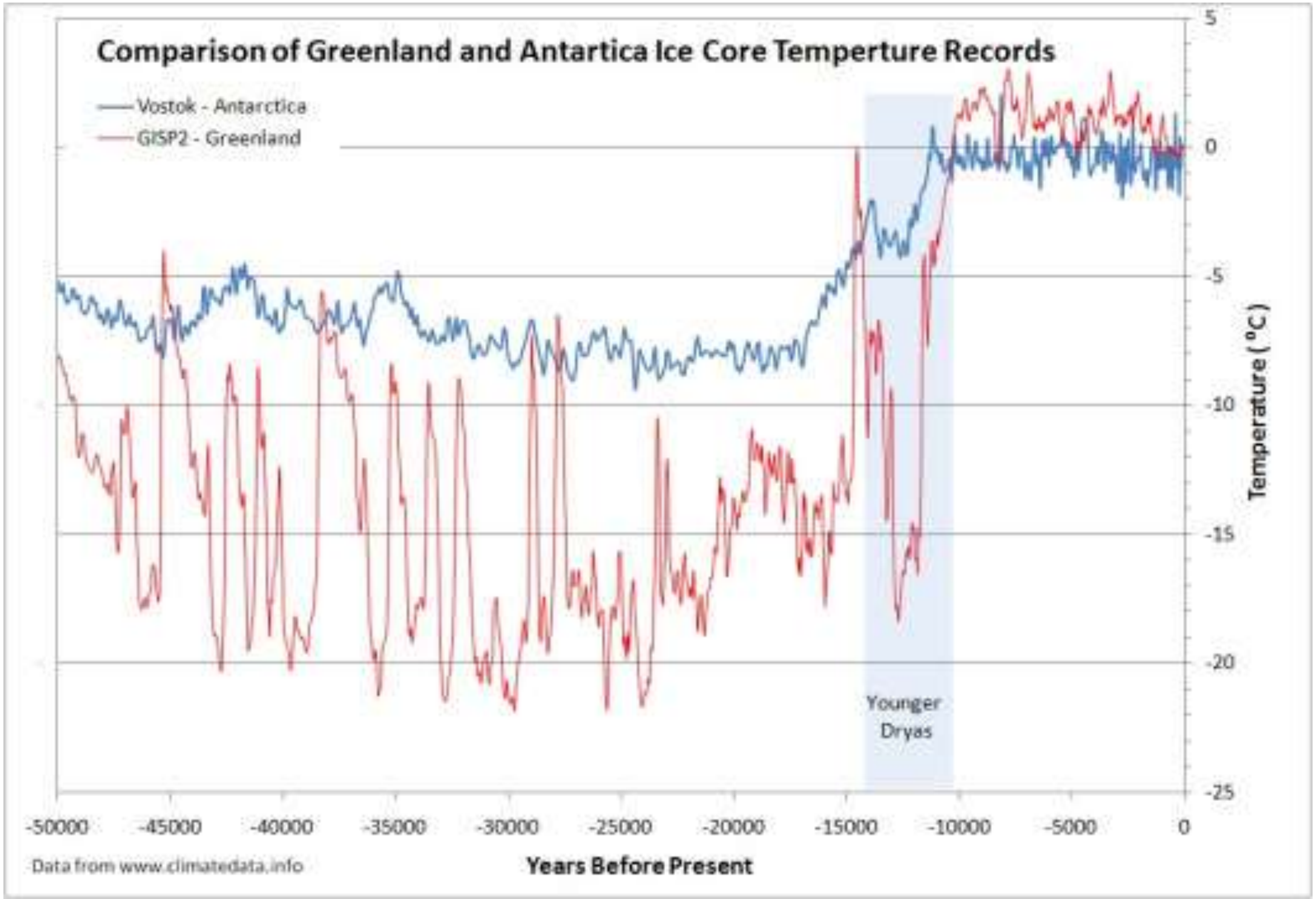




Ice core records: Antarctica



Ice core records: Greenland



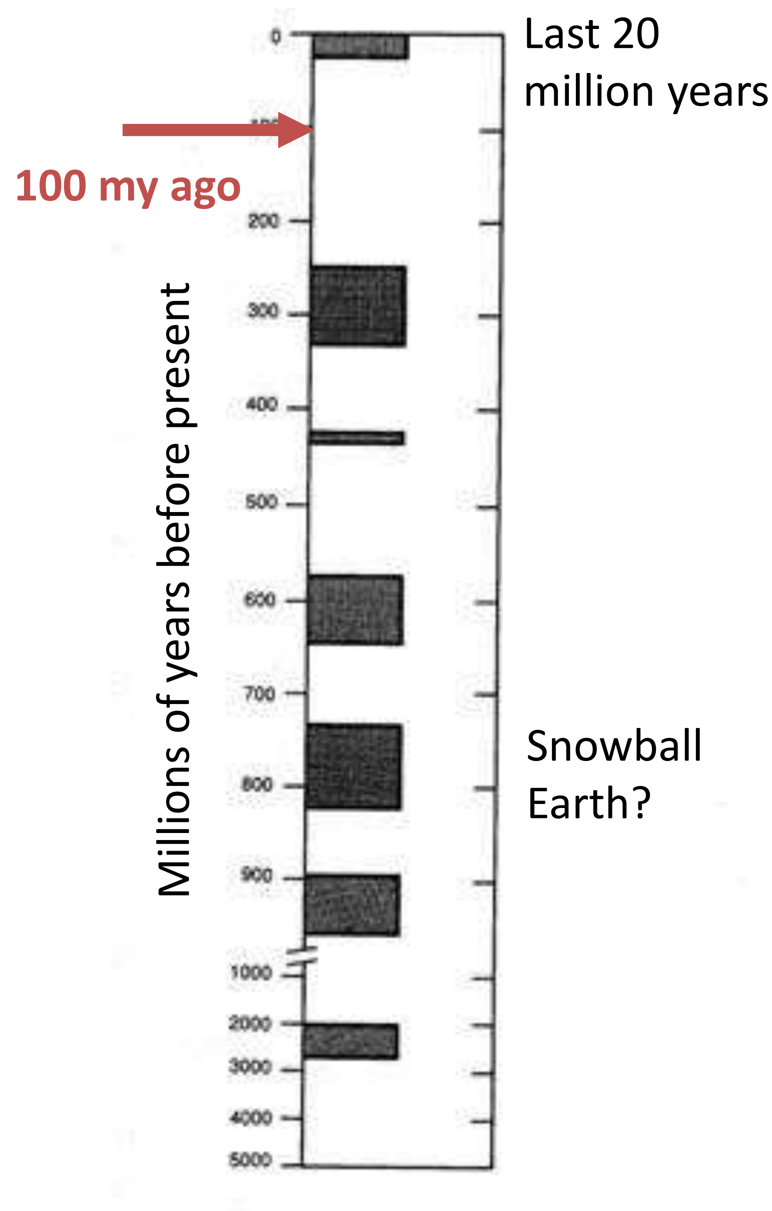
Why climate changes

1. Variations in solar output
2. Distribution of continents, mountains and oceans
3. Surface characteristics
4. Changes in greenhouse gas concentrations
5. Aerosols – affect transmission and absorption of solar and infrared radiation
6. Changes in Earth’s orbit (Milankovitch cycles)
7. Feedback processes: positive = amplifying, negative = stabilizing

History of climate over last 100 Myrs

Earth is presently in a cool period – dark bands show times when large ice sheets were present on continents.

However, during much of Earth's history, there is no evidence for ice ages – warmer oceans, warmer conditions and higher sea levels.

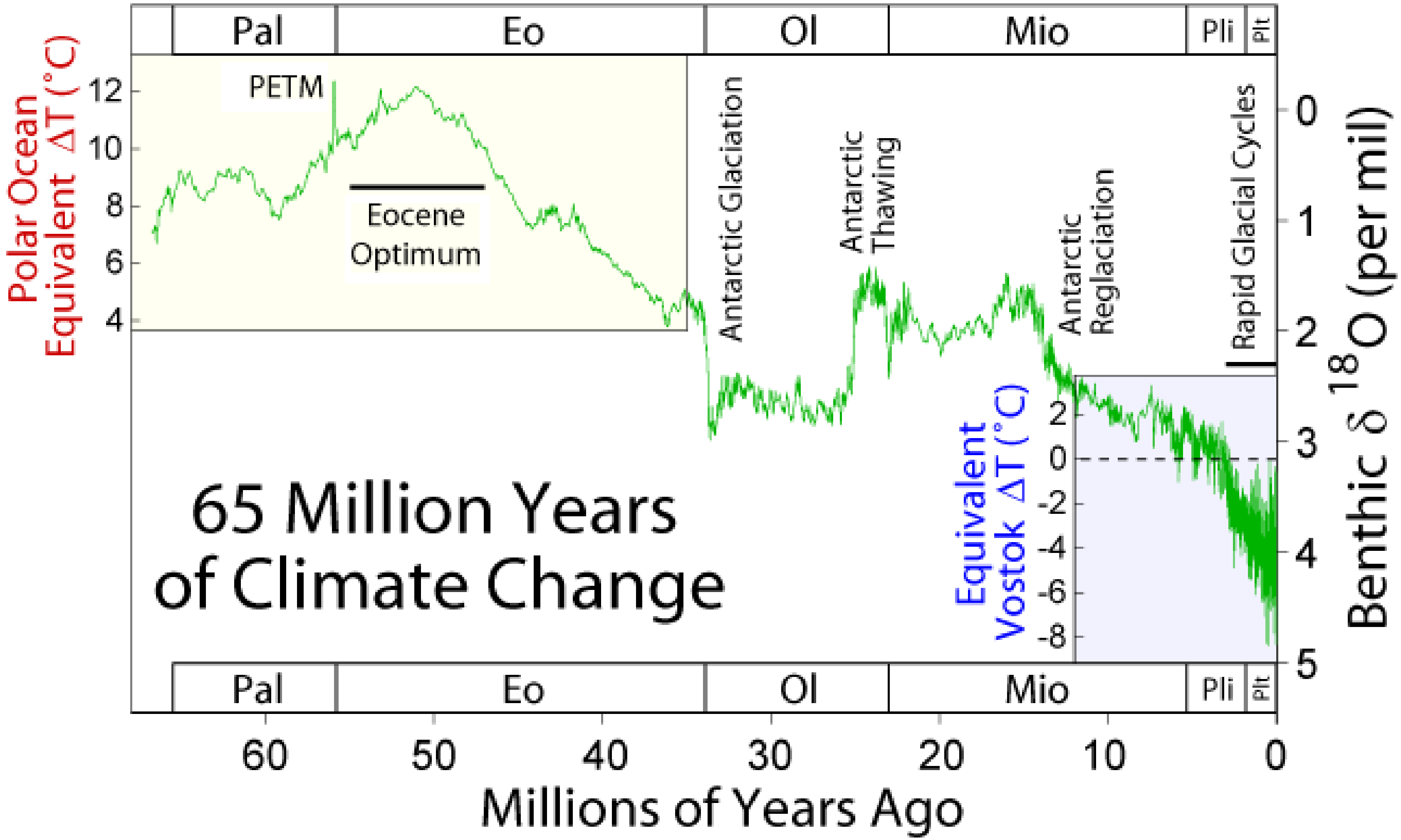


Middle Cretaceous – 100 Myrs ago

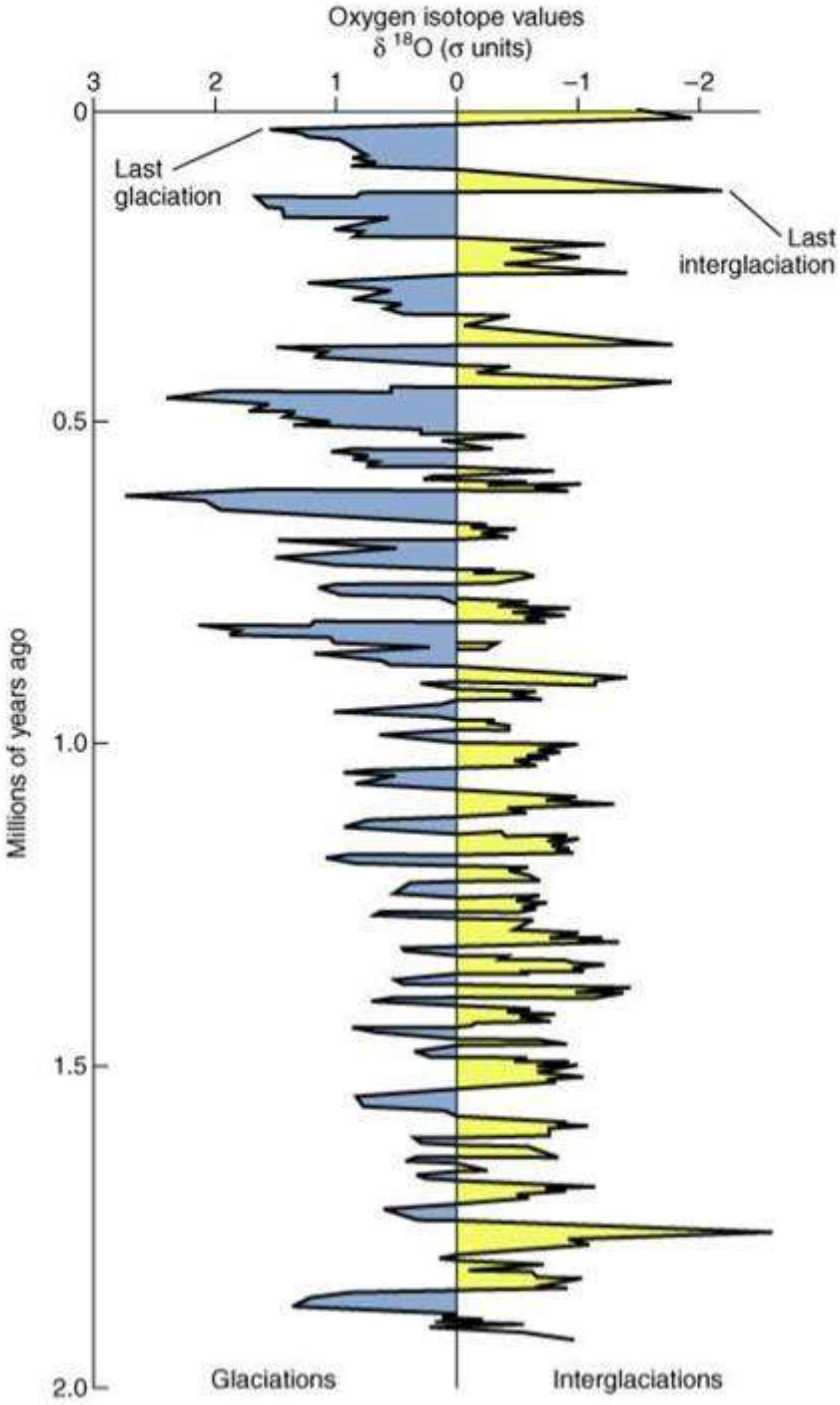
Around 100 million years ago

Antarctica during Cretaceous

Last 65 million years



Last 2 Myrs

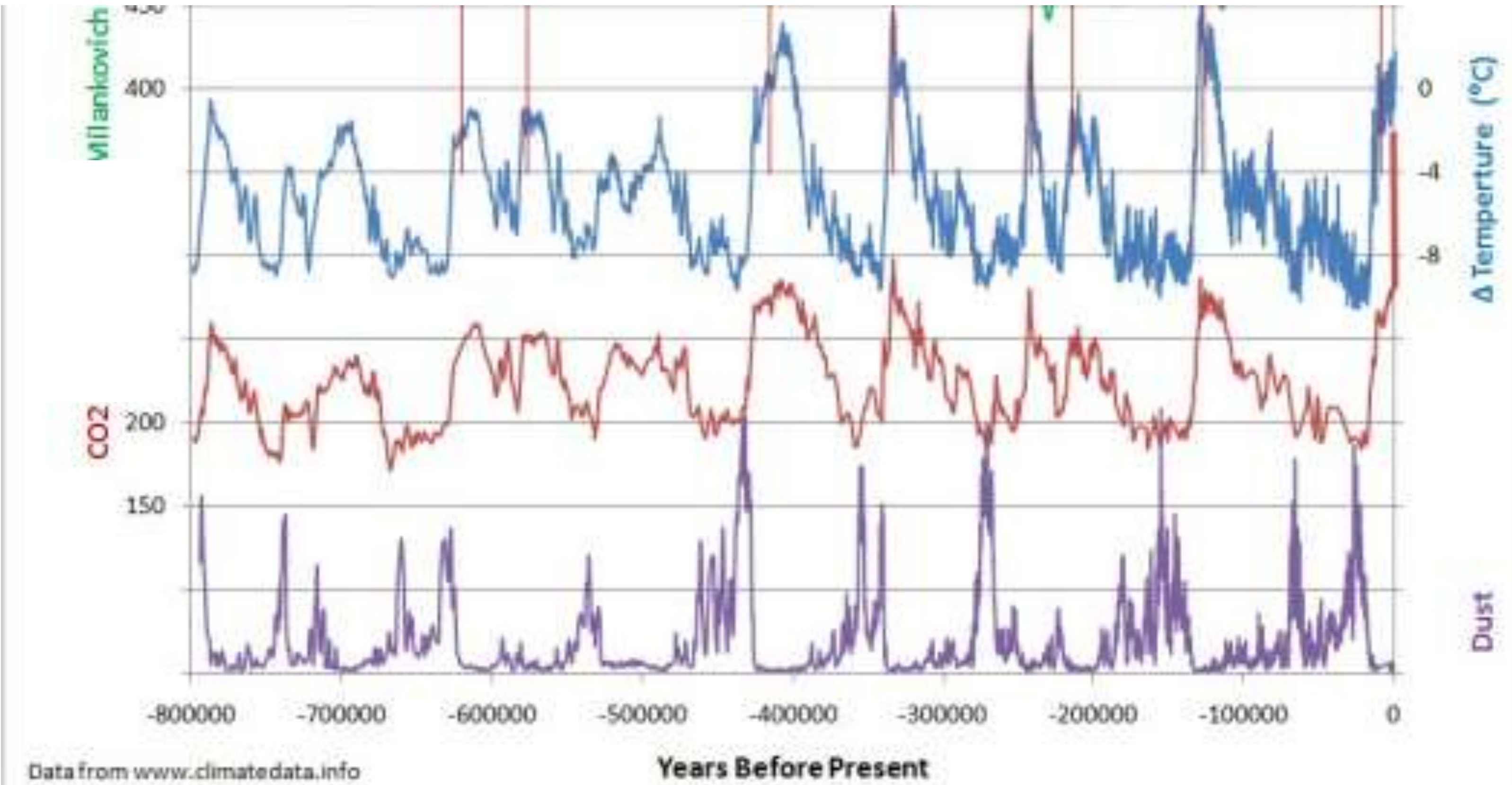


Shows cold glacial (blue) and warm interglacial (yellow) periods

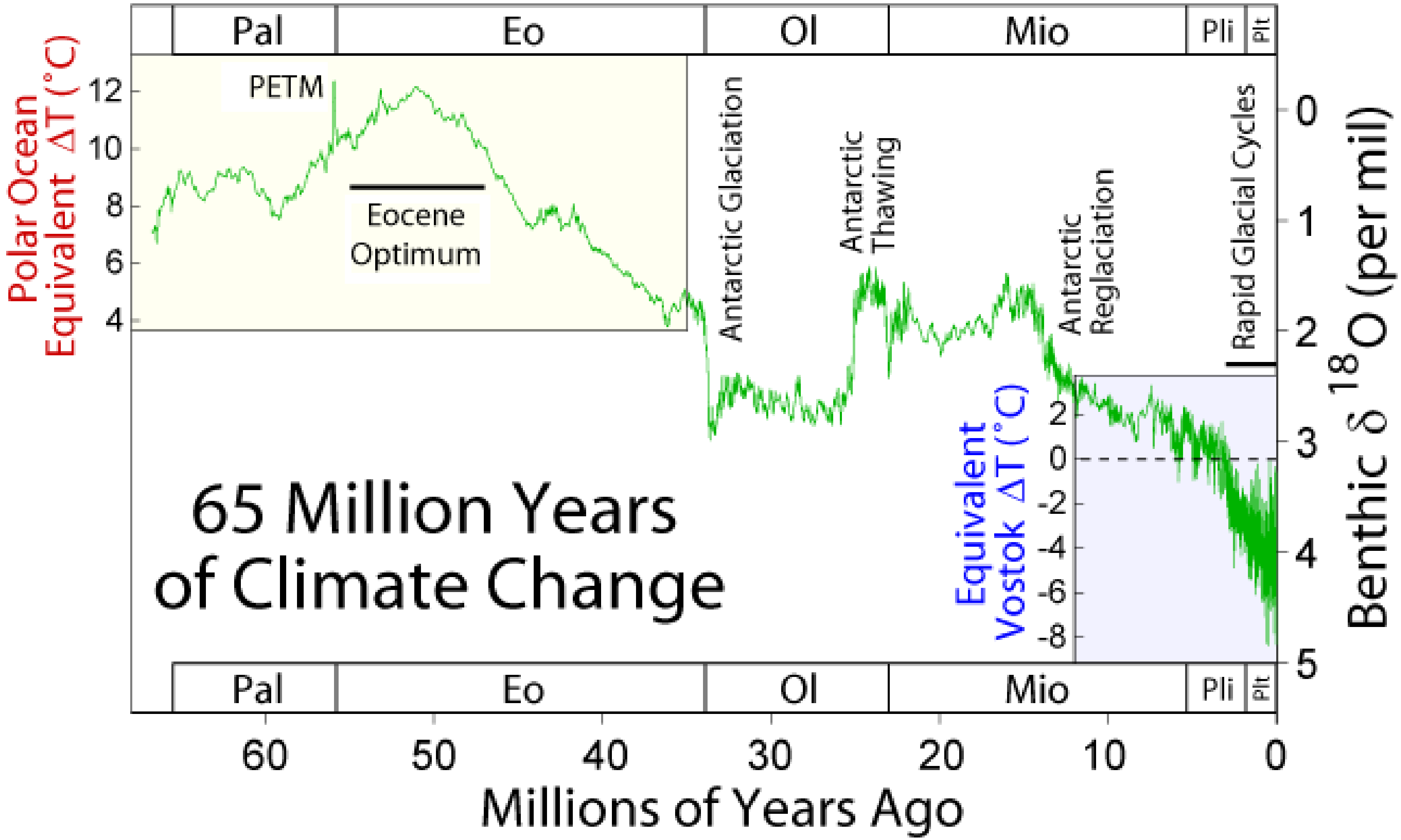
Ice ages every ~100,000 years for the most recent 800,000 years with gradual cooling then rapid warming

Climate changes due to Milankovitch cycles and amplifying climate feedbacks e.g. increased CO_2

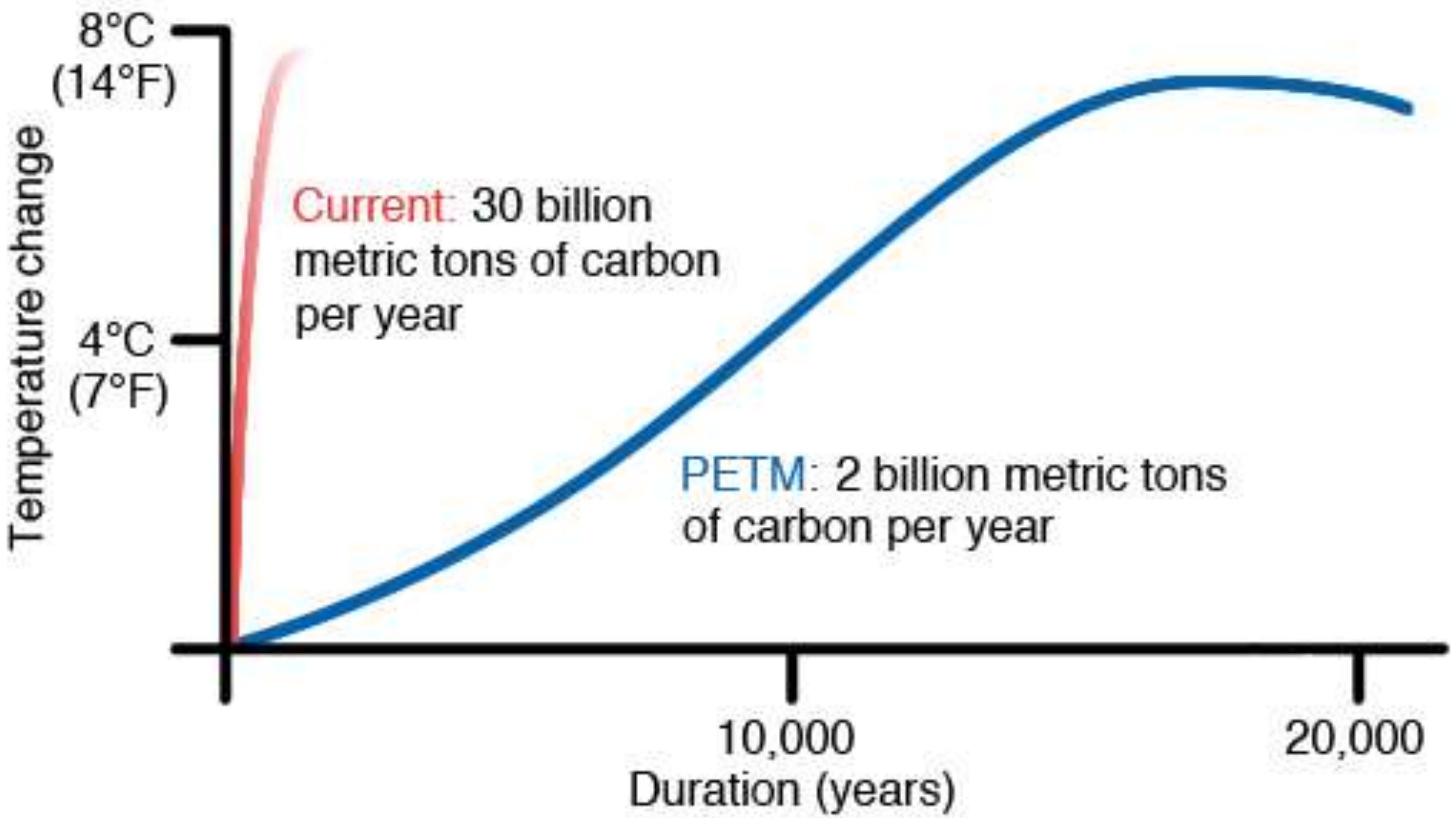
Ice core records and the carbon cycle



Case study: Paleocene-Eocene Thermal Maximum



Learning from the past: Paleocene-Eocene Thermal Maximum

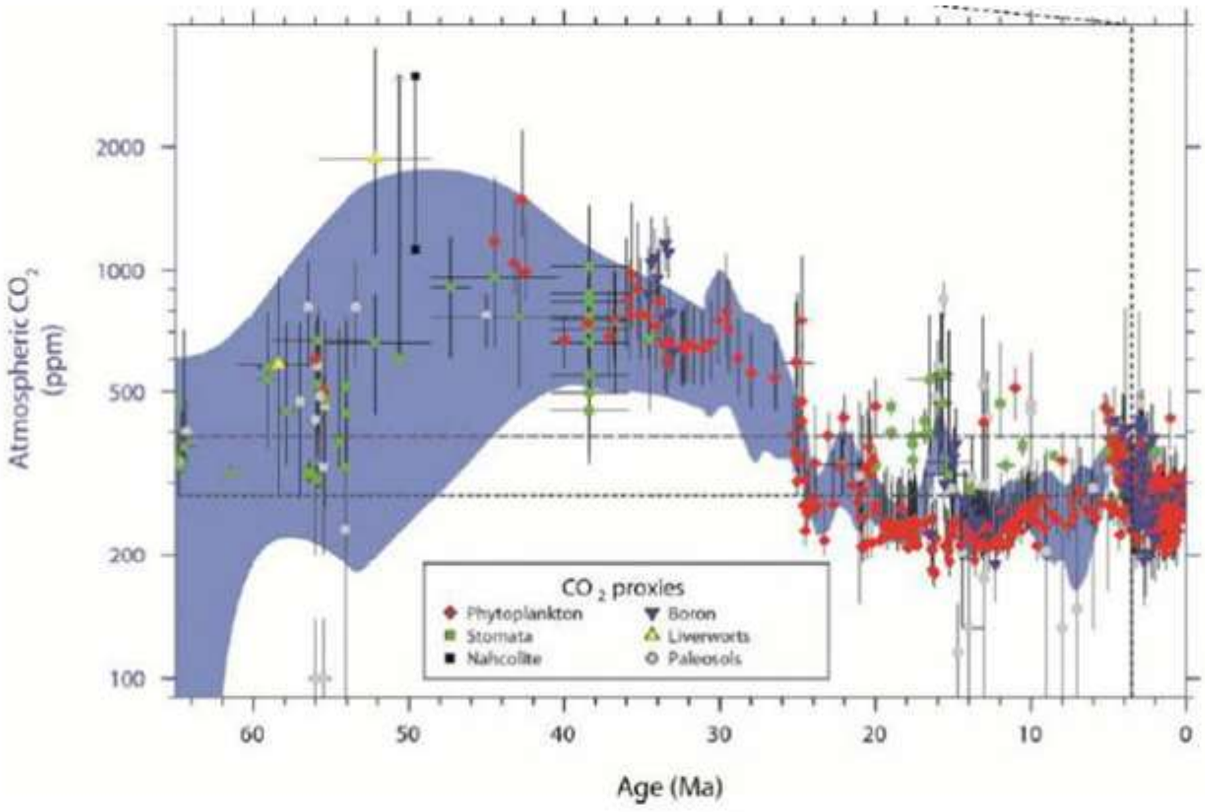


Learning from the past: Paleocene-Eocene Thermal Maximum

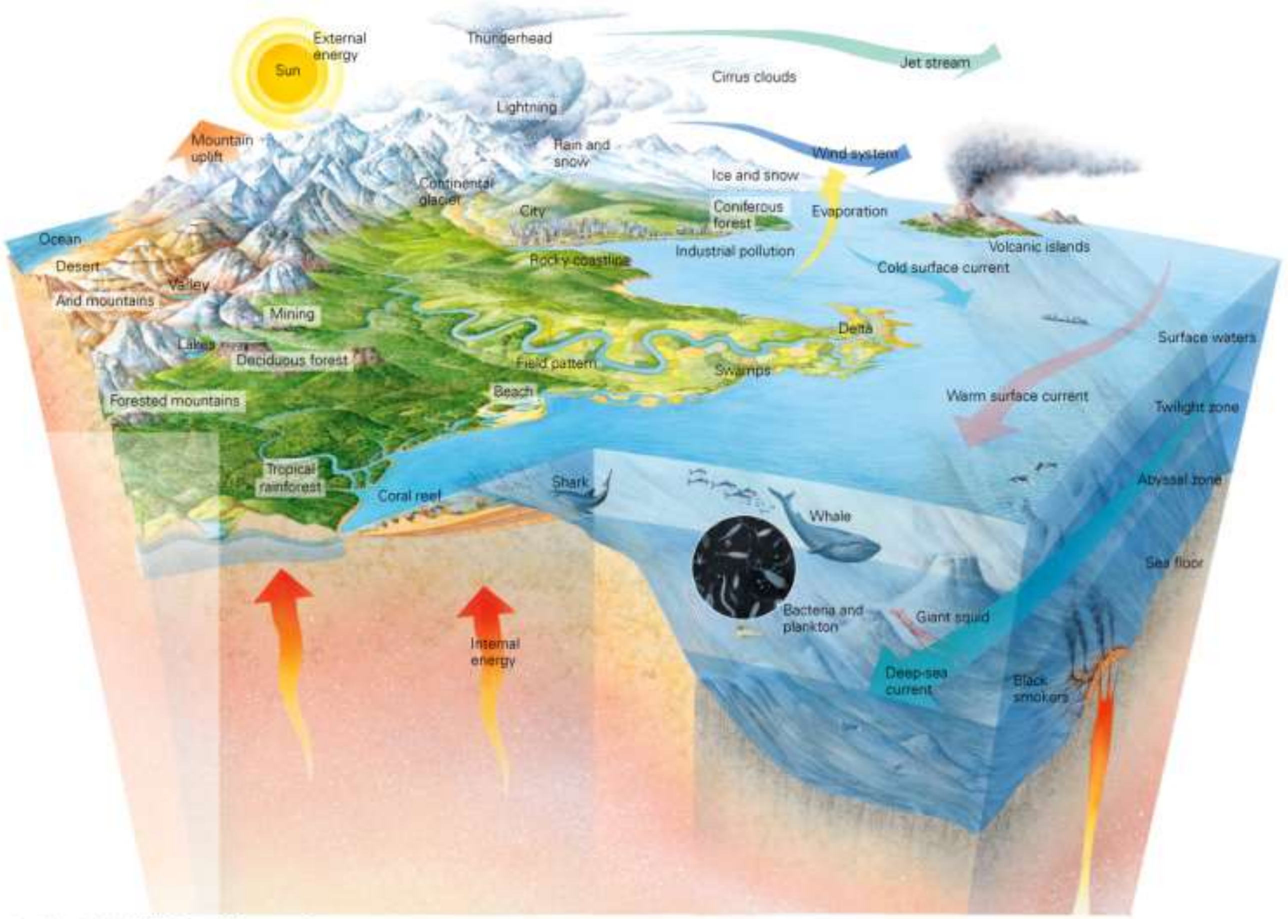
	PETM	Current Warming
Cause	Continental drift, volcanoes, methane hydrate melting, fires, permafrost melting	Anthropogenic burning of fossil fuels (oil, coal, natural gas, etc)
CO_2 emissions	Around 5 billion tons per year	At least 30 billion tons per year
Rate of warming	0.025°C per 100 years	1 to 4°C per 100 years
Environmental impact	Ocean circulation reversed, oceans acidified, permafrost melted, peatlands and forests burned in wildfires	**Observed impacts**: significant sea ice decline, extreme drought, more wildfires, increase in glacier melt, more catastrophic floods, ocean acidification, sea level rise, shoreline erosion **Potential impacts**: degraded air and water quality, permafrost melting, global ocean circulation changes, more violent winter storms and spring tornado seasons, more intense hurricanes
Ecosystem & human impact	Migration of land mammals, extinction of some benthic foraminifera, coral bleaching	**Observed impacts**: Famine and malnutrition due to drought, coral bleaching, species endangerment (e.g. polar bears, marine turtles, North Atlantic whales, giant pandas, orangutans, elephants) **Potential impacts**: increased mortality from extreme weather and malnutrition, increase in disease vectors, decrease in agricultural yield, mass wildlife migration and extinction, total societal collapse

What we've learned from paleoclimate

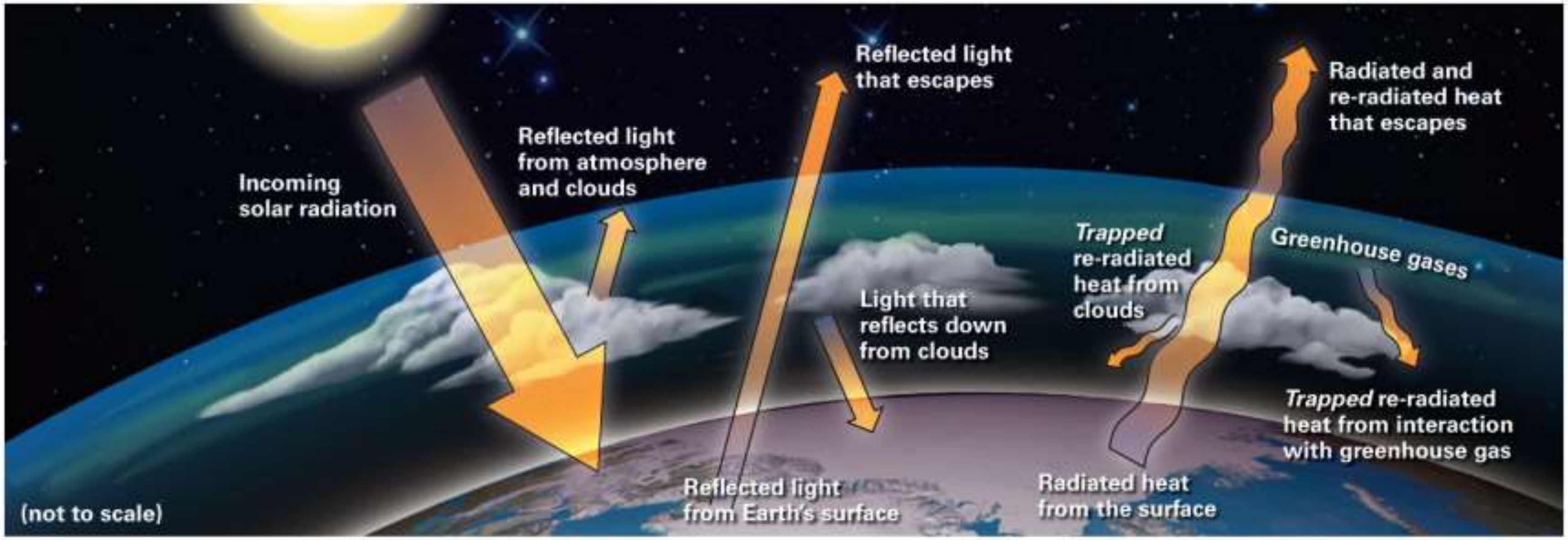
- World has been warmer and colder than today in Earth's history
- But… human civilization is very much "adapted" to the current, very stable climate
- The RATE of climate change over the next 100 years is greatest threat - likely 10 times faster than any other change in the last 65 million years



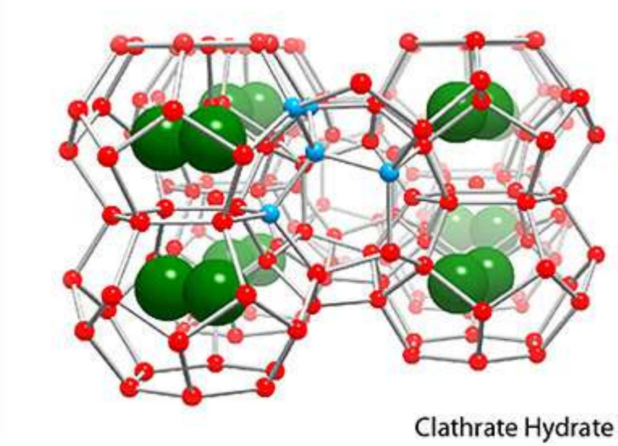
Interactions between geosphere and rest of Earth system



Interactions between geosphere and rest of Earth system

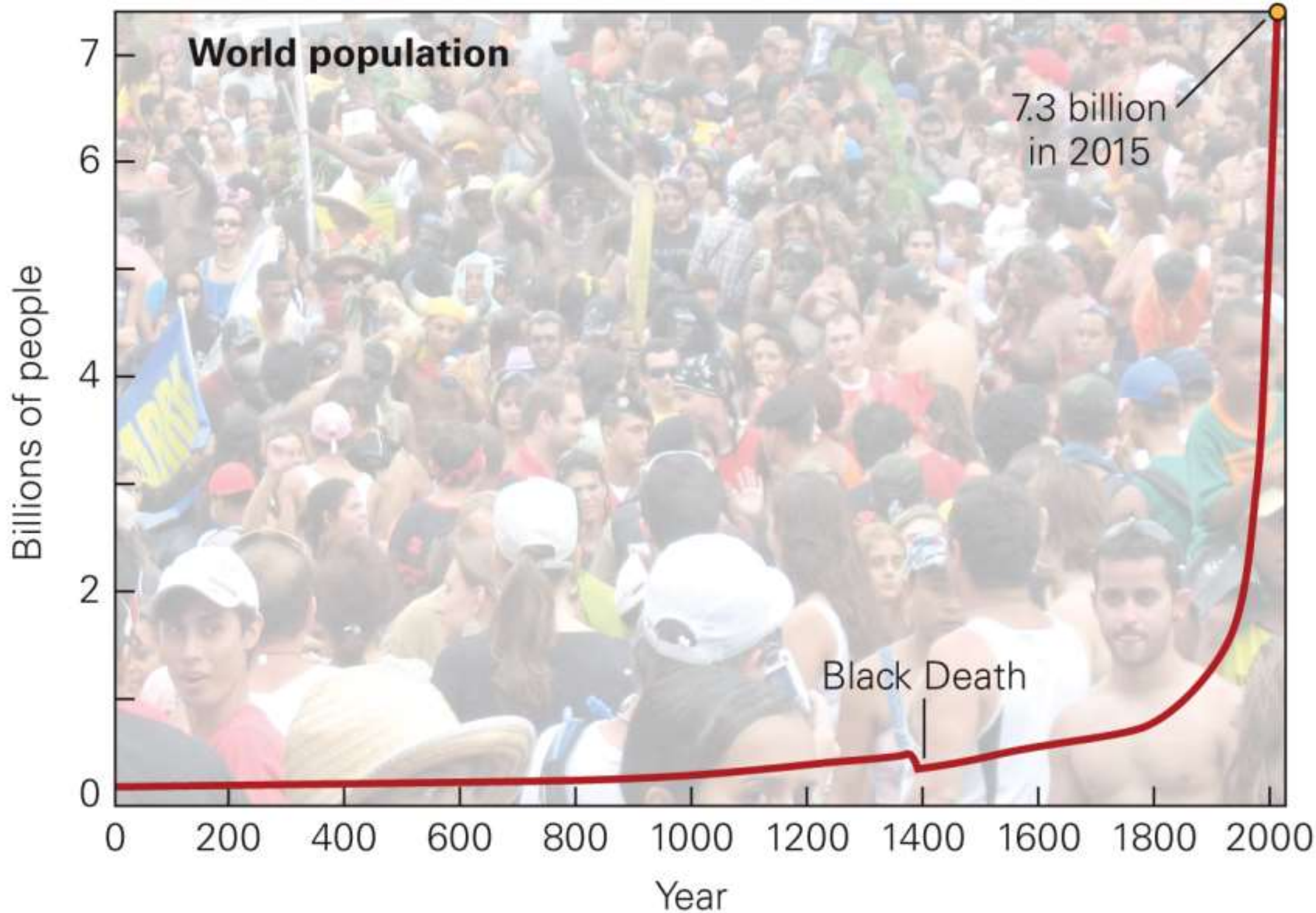


Clathrate Hydrates



Have we reached a point of no return?

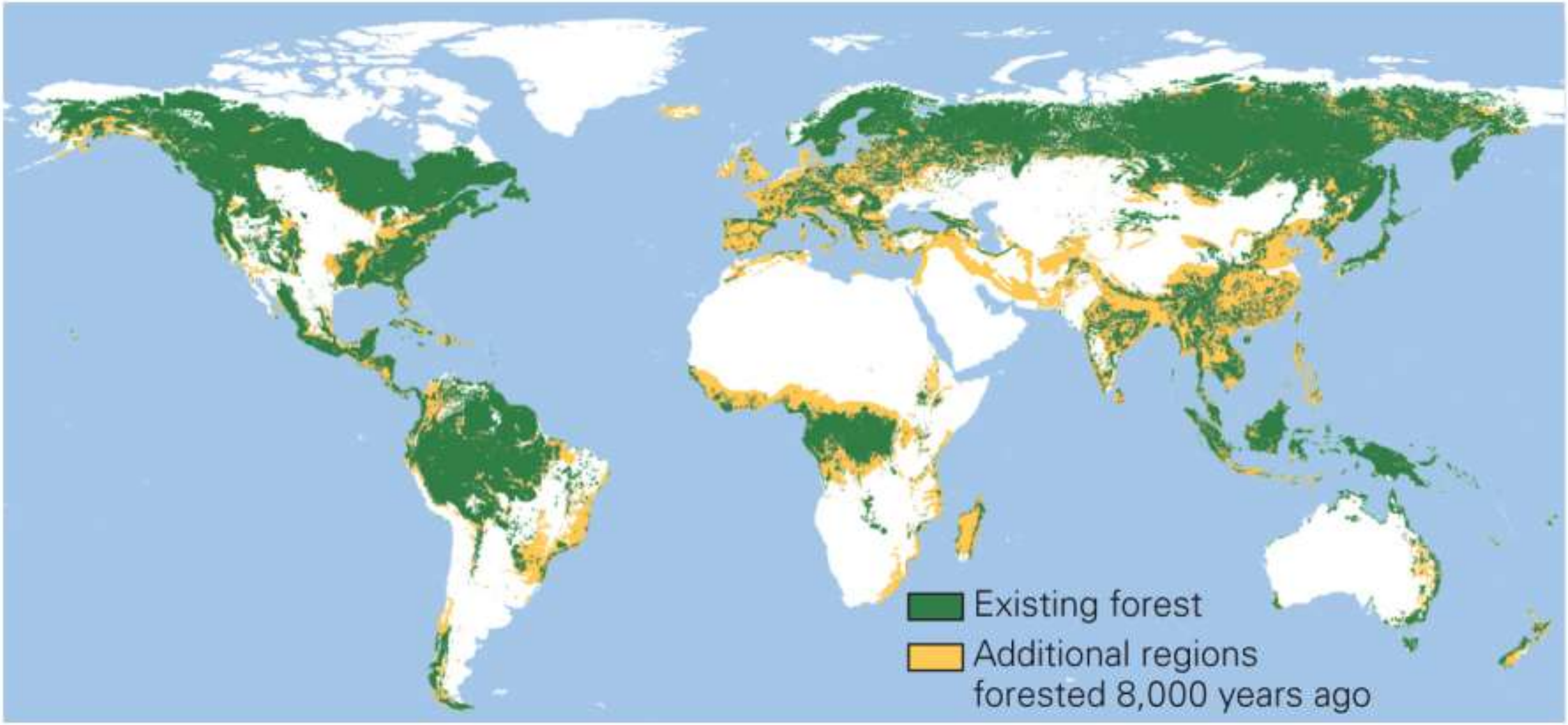
Who cares?


World population
7.3 billion in 2015
Black Death
Billions of people
0
2
4
6
7
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Year

Will 1 day of over eating have health implications?

Will 1 day of over spending have wallet implications?

Will 1 day of over eating have health implications?



Also ozone layer